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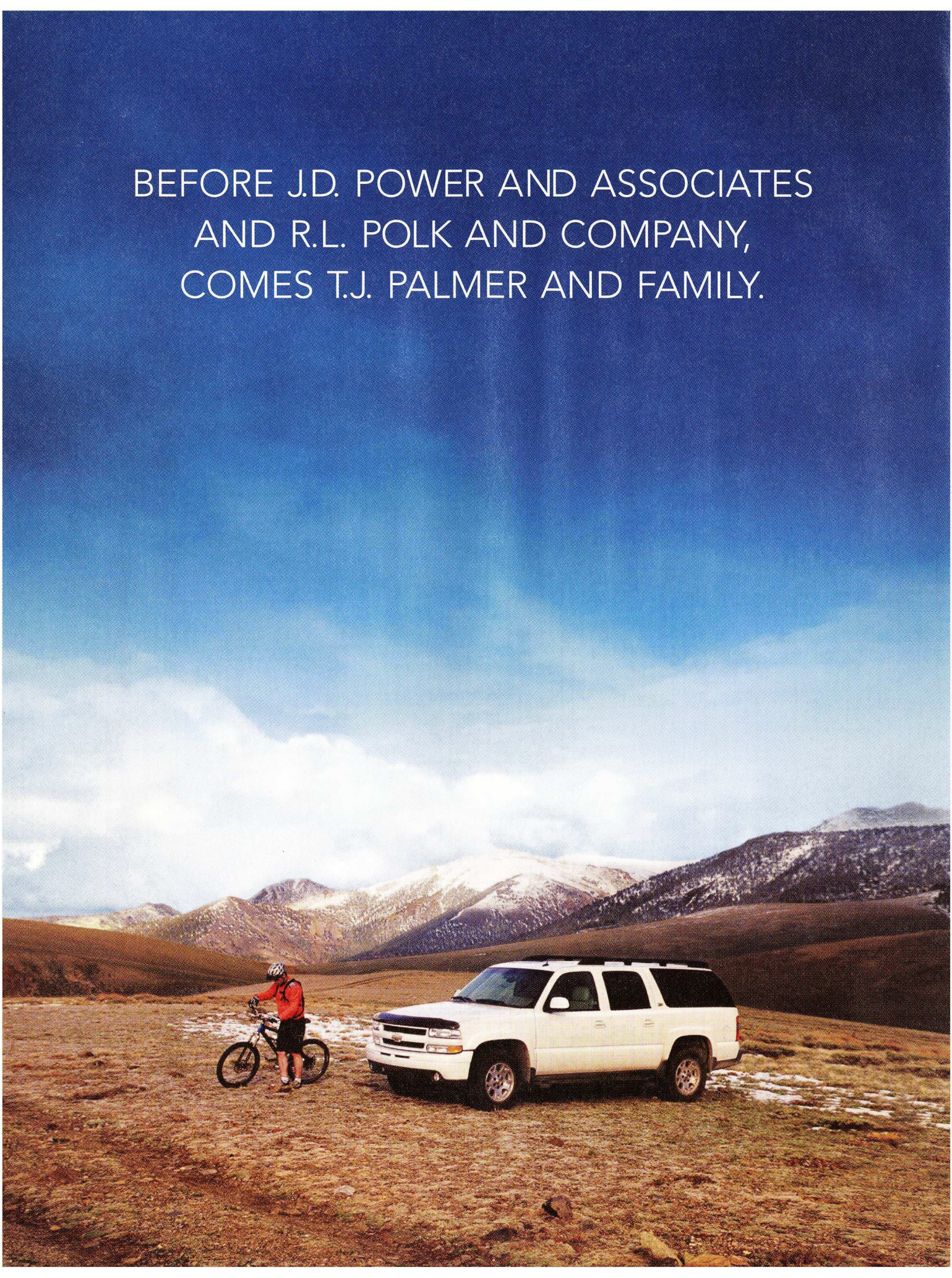
AND R.L. POLK AND COMPANY,
COMES T.J. PALMER AND FAMILY.



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*According to Polk statistics for Overall Manufacturer Loyalty in the 2000-2003 model years, General Motors ranked highest by having the greatest percentage of households return to purchase or lease another General Motors vehicle.

** General Motors Corp. – Lansing Grand River, MI (Car) plant was the highest ranked and the General Motors Corp. – Hamtramck, MI plant was the second highest ranked in North/South America among plants producing vehicles for the U.S. market. J.D. Power and Associates 2003-2004 Initial Quality Studies℠ 2004 Study based on a total of 51,208 U.S. consumer responses including owner reported problems during the first 90 days of ownership. www.jdpower.com

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Cover photograph by Christopher Harting

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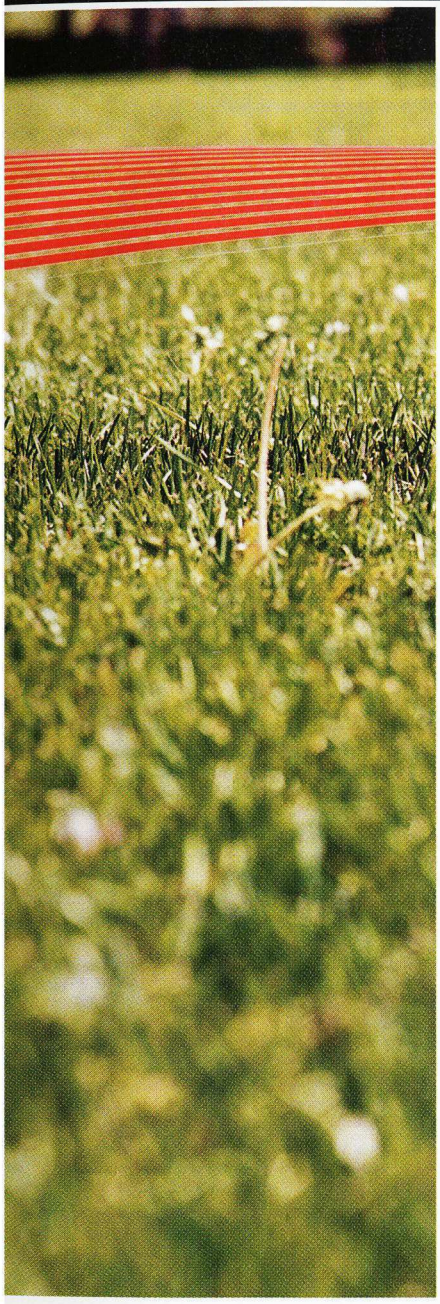
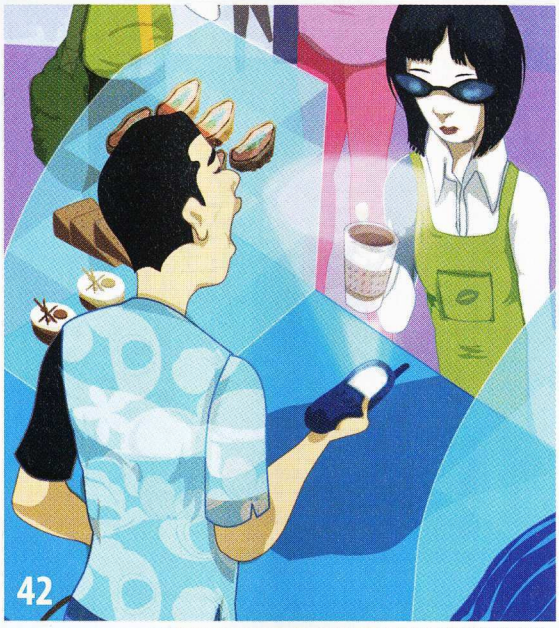
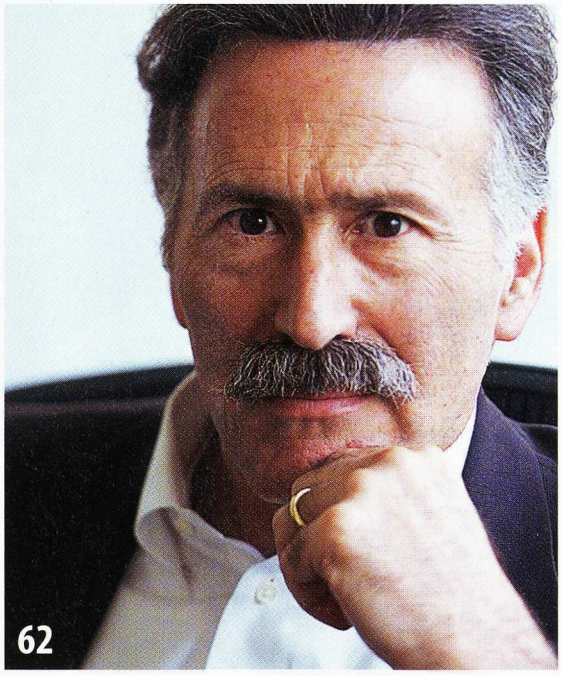
Technology Review
Volume 107, Number 6
July/August 2004

"The phone will replace the wallet in five years."
—Takeshi Natsuno, p. 48







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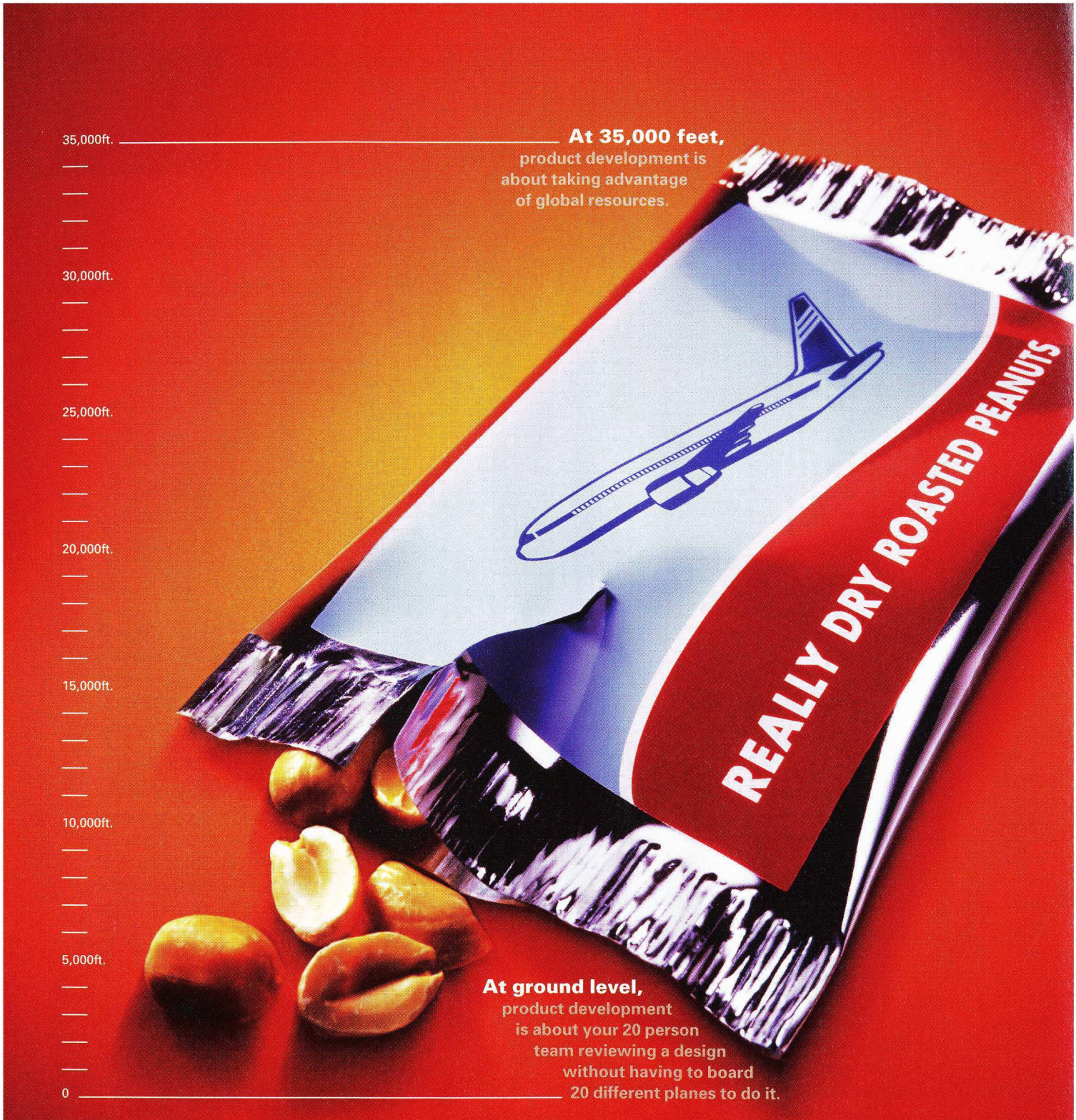

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The Other IPO

I KNOW, IF YOU HEAR any more about a particular Internet search-engine company going public, you'll likely find yourself Googling "quick remedies migraine." A few insiders get filthy rich. A couple of computer science grad students clever enough to turn a research project into a company become Silicon Valley's newest rock stars. And venture capitalists lucky enough to jump in early gain status as technology pundits. It's clever technology, but when all is said and done, it's hardly earth-changing stuff.

But there is a technology IPO in the works that you should keep an eye on. As you will read on page 29 (in one of the magazine's new departments—but more on that later), Nanosys, a startup in Palo Alto, CA, has filed papers with the U.S. Securities and Exchange Commission to become the first significant company born of the recent advances in nanoscience to go public. And this *is* earth-changing stuff: Nanosys is creating nanoelectronics that could make computers and displays unimaginably fast and efficient. Even more exciting, as this month's cover story *(p. 34)* explains, Nanosys and a number of other companies are exploiting nanotechnology to make new types of solar cells that could make energy cheap and abundant. Nanosys has plenty of competition in the area of nano solar cells, but it has clearly spotted an application where nanotech can make a huge difference.

Unlike that other IPO, this one is unlikely to make anyone an instant billionaire. Still, Nanosys's IPO—if and when it happens—will be a milestone in the maturation of the often hyped but nevertheless promising field of nanotech. Nanosys readily admits it is still at least several years from having commercial products. But the history of technology shows the importance of patience. Consider the birth of the biotech industry. Genentech, which is now a $3.3 billion company, helped launch that sector with its IPO in 1980, five years before marketing an initial product.

So what will Nanosys's IPO say about the immediate prospects of nanotech? Maybe not much. An initial public offering should not be confused with nanotech's public debut. That's already happening. And it will take years—and much patience and perseverance—for the new technology to fully become a part of our lives. But Nanosys's IPO will send a signal to other promising startups in the field: it's time to move forward on that difficult challenge.

THIS ISSUE MARKS the debut of three new departments dedicated to the latest news in information technology, biotech, and nanotech. These topics have been at the core of *Technology Review*'s coverage for several years, so it is only fitting that each gain its own distinct place in the pages of the magazine. **David Rotman**

NEXT ISSUE

Hollywood's Visual-Effects Visionaries
Photorealistic, computer-generated human faces have long evaded the best animators in the motion picture industry. But researchers at Sony Pictures Imageworks in Culver City, CA, are creating perhaps the most advanced digital actors ever to hit the silver screen. That means more-realistic action scenes—and more-believable close-ups of "real" actors performing unbelievable stunts.

Genes to Drugs
Using a database brimming with centuries-old medical information about nearly half of Iceland's inhabitants, deCODE Genetics is homing in on disease-causing genes and developing the drugs to target them. The company is one of the first realizing the dream of personalized medicine: prescribing treatments on the basis of an individual's unique genetic profile.

Open Source Closes In
As open-source software giant Linux continues its impressive inroads against Microsoft and other proprietary software makers, will it lose its ideals of openness and sharing? *Technology Review* looks inside the business of Linux and talks about open source's trajectory with Miguel de Icaza, cofounder of Ximian, a leading producer of Linux-based desktop systems that was recently acquired by Novell.

Q&A with Carver Mead
Carver Mead is one of Silicon Valley's intellectual-property godfathers, with more than 20 startups to his credit. Among his successes: touch-pad maker Synaptics and the revolutionary image-chip startup Foveon. We talk to him about the nature of innovation—and what's next in biologically inspired computing.

And more...

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INVENTION'S GIANTS

HOWARD ANDERSON IS WRONG WHEN he says big companies can't invent ("Why Big Companies Can't Invent," *TR* May 2004). While big companies have had to adjust to the rapidly changing rate of innovation and market dynamics, some of them are adjusting quite nicely. Take the company I recently retired from: IBM. When wireless technology emerged, a group of IBM "intrapreneurs" came together to take advantage of IBM's Research division. As a result, revenues for wireless e-business services catapulted from $300 million to $2.4 billion within two years. The group that accomplished this navigated internal barriers and was not preoccupied with compensation. They realized that failure does not necessarily lead to the demise of the company, as it can with startups. To put it in terms of Anderson's metaphor: large companies realize that attack is the best form of defense!

Perminder Bindra
Patterson, NY

I NOTICED SOMETHING STRANGE ABOUT the May 2004 issue. First you have an article about how big companies can't invent, and then the very next article is about Microsoft reinventing the pen ("Microsoft's Magic Pen"). If this pen starts selling well, which it probably will, then maybe it shows that big companies *can* invent.

Zack Green
Syosset, NY

"If this pen starts selling well, which it probably will, then maybe it shows that big companies *can* invent."

The editors respond: We tried to air many viewpoints on the changing nature of invention in our issue. Anderson's essay expressed his opinion. Not everyone, including most big firms we know, agrees.

THERE IS ANOTHER REASON WHY research and development in a big company can be wasteful. Corporate R&D is logical and efficient while invention is chaotic. It is much more efficient for a corporation to let the little companies explore every crevice. Then a smart corporation buys the results or even the company that has stumbled into improvements on the corporation's products. Take, for example, the expansion cards for the IBM PC. IBM introduced the PC with few such cards already installed. The company knew it couldn't divine the market, so it simply produced a viable open platform and waited. Modems took off. IBM introduced one. Clock calendars took off. IBM introduced one. Why waste money and energy on technology development and market research? Wait, watch, and buy or copy.

Steven D. Edelson
Shadow Laboratories
Wayland, MA

MULTIPLE MAGIC PENS

GREGORY HUANG'S LOOK INSIDE MICrosoft's Beijing lab was fun but left me wondering how Microsoft's pen compares to other digital pens ("Microsoft's Magic Pen," *TR* May 2004). Microsoft's pen and patterned paper seem very similar to Anoto's pen and patterned paper. What's different about Microsoft's pen?

Duncan Lissett
Mountain View, CA

The editors respond: What is unique about the Microsoft pen is its software. When a user prints out a document, the software encodes it with a background pattern that lets the system know where the pen is as it marks the paper. The user can then modify the digital file by writing on the hard copy. Digital pens on the market don't modify existing printed documents in this way. But Anoto and its partners are developing similar technologies.

A LICENSING LEARNING CURVE

I RECENTLY FINISHED READING *THE Chip: How Two Americans Invented the Microchip and Launched a Revolution*, by T. R. Reid, published in 1984, about the conception, development, and marketing of the microprocessor. It describes how U.S. firms take the lead in developing new technologies, only to see themselves overwhelmed in the marketplace by foreign manufacturers. Why? Because they license their critical technologies to the very firms who then build successfully on those technologies. That was 20 years ago. Now I read in your May issue that both InPhase Technologies and Aprilis will be licensing their new holographic storage technologies to Sony and Sanyo to bring to market ("Holostorage for the Desktop," Innovation News). For all the alleged brainpower in this country, we don't seem to learn very quickly.

James L. Hall
East Hartford, CT

CORRECTION: Our story "Sparking the Fire of Invention" (*TR* May 2004) should have said that foreign entities will likely account for the majority of patents granted, not patents filed, from 2004 onward.

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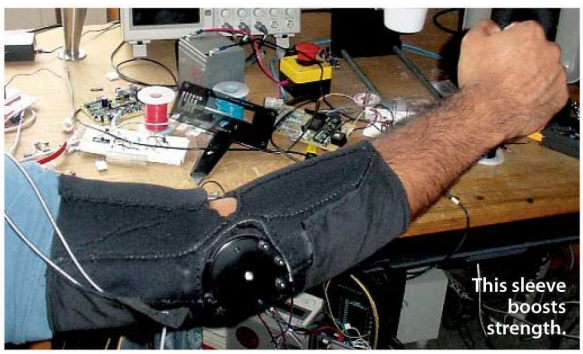
An arachnoid-like device turns silkworm proteins into spider silk.

SPINNING A (SILK) YARN

SPIDER SILK IS AMONG THE STRONGEST MATERIALS KNOWN, BUT AN ARTIFICIAL version whose strength matches the original's has proven difficult to produce commercially. Now spider experts at the University of Oxford, England, have developed a device they believe holds promise for breaking that barrier by mimicking arachnoid spinning. The researchers have founded a company, Spinox, to commercialize the technology. Starting with proteins from silkworms, the device produces highly lustrous fibers only about 15 to 20 micrometers in diameter. Spinox's device uses a special membrane to mimic the conditions in a spider's silk-making organ; under these conditions, the proteins self-assemble into nanofibrils. Making larger fibers out of the nanofibrils is simple, says cofounder David Knight: "You just pull it out of the device. The molecules stick together in the actual device and come out as a beautiful thread." Possible uses include medical implants, safety belts, composite materials for car body parts, protective clothing, durable sneakers—just about anything that could benefit from an ultrastrong, superlight material, Knight says. The researchers are working to refine the spinning device and believe that artificially spun fibers as strong and flexible as spider silk could be on the market in three to five years.

POWER ELBOW

FOR PEOPLE WITH SPINAL-cord injuries, just trying to feed themselves or pick up objects can be exhausting and frustrating. MIT researchers Kailas Narendran and John McBean, working with mechanical engineer Woodie Flowers, have built a powered elbow brace that allows patients to bend and extend their arms under their own control. Carried in a hip pack is a small electric motor that drives the elbow brace via a set of miniature cables. Electrodes placed on the skin pick up electrical signals from the biceps muscle as the wearer flexes his or her arm; a control box interprets these signals and commands the motor to move the elbow joint with just the right amount of force to let the patient, for instance, wave or pick up a cup. Initial tests have been completed on spinal-injury patients at Spaulding Rehabilitation Hospital in Boston; a larger clinical study is now under way, says Narendran, who with McBean is starting up a company this summer to develop the product.

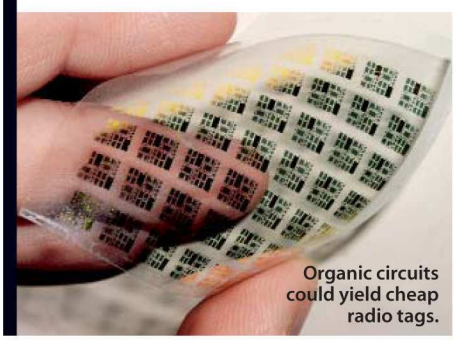

This sleeve boosts strength.

DESKTOP DASHBOARD

These days, finding information on the Web can be easier than finding it on your computer's hard drive. But Nat Friedman, a software engineer and open-source-programming guru in Cambridge, MA, is leading an effort to change that with a free program called Dashboard. Dashboard constantly combs through your e-mail, calendar, address book, word-processing, and browser programs and brings together information related to your current tasks before you even know you want it. Say you're reading an e-mail from a collaborator on a project. Dashboard automatically shows the person's contact information, her last five e-mails, and your upcoming appointments with her. Programs like Microsoft's Longhorn will have similar functions but are years from completion. Friedman, cofounder of open-source desktop software maker Ximian, which was acquired by Novell last August, says Dashboard will be ready as early as this summer.

CHEAPER RADIO TAGS

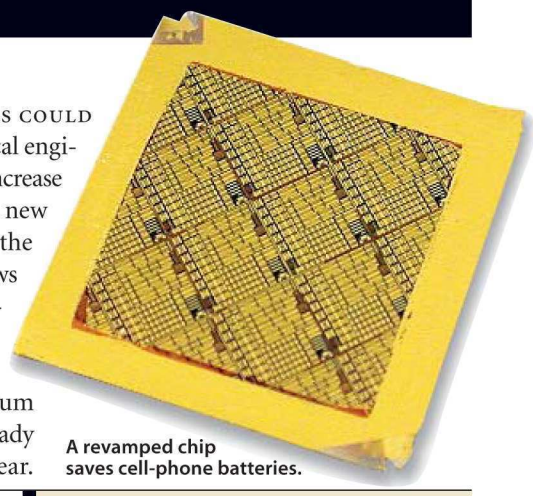
INCORPORATING RADIO FREQUENCY identification (RFID) chips into shampoo bottles, soup cans, and other products would allow suppliers and retailers to better identify and track goods. A research group led by Paul Baude at 3M in St. Paul, MN, is developing RFID chips that could be cheaper alternatives to those made from silicon, which cost around 20 cents each. The key: using pentacene as the chips' semiconducting material. Existing prototypes of the chips are built on glass or plastic surfaces; the glass versions can communicate with a reading device several centimeters away. The 3M researchers are working on increasing that distance and getting the plastic version to communicate with the reader as well.


Organic circuits could yield cheap radio tags.

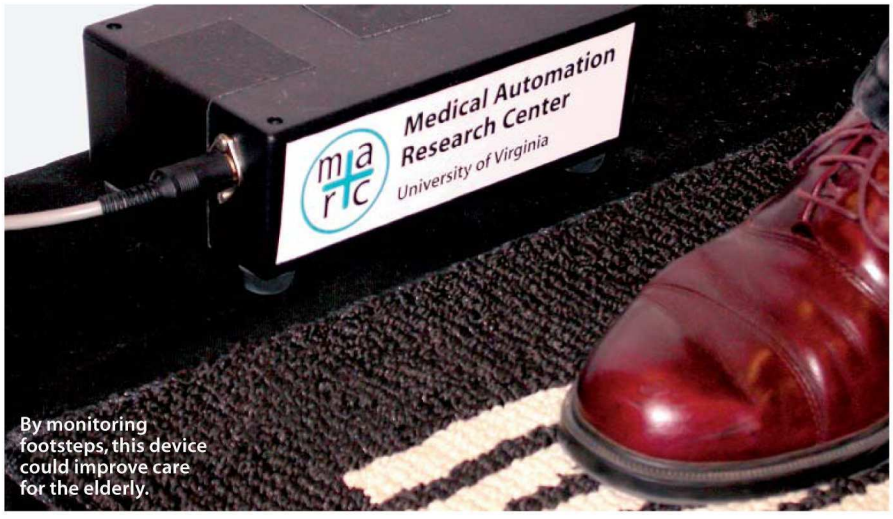
COURTESY OF PAUL BAUDE (TAGS); COURTESY OF MIT ACTIVE JOINT BRACE (ELBOW); COURTESY OF BOURNEMOUTH NEWS AND PICTURES SERVICE (SPINNING)

WIRELESS POWER BOOSTER

BATTERY-HOGGING, STATIC-RIDDEN CELL PHONES AND OTHER WIRELESS DEVICES COULD soon be a thing of the past. Zhenqiang Ma, a University of Wisconsin-Madison electrical engineer, says he has redesigned a key electronic component in wireless devices so that it can increase the strength of outgoing signals while saving battery power. Ma has come up with a new arrangement of transistors for the power amplifier, the component that boosts the strength of an electrical signal before sending it to a device's antenna. The new design allows for easier and more uniform heat dissipation. Since excessive heat lowers power amplification, this translates into a stronger signal and less wasted battery power; a cell-phone user could get 25 percent more talk time out of each battery charge. Ma has produced silicon chips that use his new design and is now working on versions made from gallium arsenide, the most common semiconductor for cell phones. He says his technology is ready to be licensed by a chip maker and could be on the market as early as the end of this year.



A revamped chip saves cell-phone batteries.



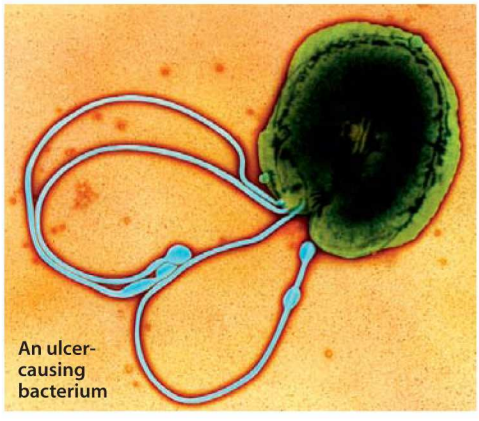
By monitoring footsteps, this device could improve care for the elderly.

HEARING STEPS

THE FLOORS HAVE EARS. BIOMEDICAL ENGINEER MAJD ALWAN AND HIS COLLEAGUES AT the University of Virginia have developed a device that analyzes the footstep patterns of the elderly to detect falls and give early warning of certain diseases. Unlike monitors that require users to wear sensors, walk on special platforms, or be videotaped, this device sits on the floor unobtrusively. The brick-size box contains a sensor that measures tiny vibrations and a microprocessor that learns a person's normal walking habits and uses signal-processing algorithms to detect changes. If the person falls, or limps or shuffles—warning signs of diseases such as osteoarthritis or Parkinson's—the monitor alerts a computer to send a message to a caregiver. The goal, says Alwan, is to "bring gait analysis out of the lab and into the home." His team recently spun off a company to commercialize the device, which could be placed in homes and assisted-living facilities within a year.

CAR POOL COORDINATION

It's already happening in a few cities. Lone drivers who want to use car pool lanes can stop at informal gathering spots to pick up passengers who need rides. But passengers aren't always going to the same destinations as drivers—and some drivers prefer quiet passengers to talkative ones. So information science researchers Paul Resnick of the University of Michigan in Ann Arbor and Marc Smith at Microsoft are creating a computerized system that will make it easier for drivers and passengers in any city to find happy car pool matches. Called RideNow, the system starts with a Web interface where users can log in, specify their preferences, and enter their destinations and the approximate times at which they want to travel. Software matches up drivers and passengers, calls both parties' cell phones, and patches the calls together so that the users can negotiate a meeting place. Resnick says tests of the system should start this fall in Ann Arbor. Later, Resnick hopes, startups might want to commercialize the service in cities without extensive public transportation, perhaps charging a subscription fee.



An ulcer-causing bacterium

ZAPPING ULCERS

IF YOUR DOCTOR THINKS YOU HAVE AN ULCER, YOU MAY HAVE TO SWALLOW A special camera called an endoscope to find out for sure. The good news: in about a year doctors may be able to quickly and painlessly cure the ulcer at the same time, thanks to a device from Boston, MA-based startup LumeRx. The company is developing a fiber-optic device that can be passed into the stomach alongside the endoscope. In a procedure that takes only five to 10 minutes, the device beams out blue light specially tuned to kill a bacterium called *Helicobacter pylori*, which causes up to 90 percent of ulcers. Should the approach prove itself in human tests planned for this summer and gain U.S. Food and Drug Administration approval, it could offer an alternative to today's standard ulcer treatment: a one- to two-week course of antibiotics that can cause nausea and other side effects and which could ultimately promote the development of resistant strains of bacteria.

CAMR/A. B. DOWSETT/PHOTO RESEARCHERS (ULCERS); COURTESY OF MEDICAL AUTOMATION RESEARCH CENTER (STEPS); COURTESY OF THE UNIVERSITY OF WISCONSIN-MADISON (POWER BOOSTER)

Prepared Minds Favor Chance

DEPRESSED? MERCK'S RESEARCH NEUROSCIENTISTS would have reason to be. The pharma giant bet a fortune over the past decade that a novel compound that blocks a neurotransmitter called "Substance P" would become an effective new treatment for depression—a multibillion-dollar global market profitably dominated by Prozac, Paxil, and Zoloft. Merck bet wrong. Its aspiring antidepressant performed well in early experiments but flunked the phase III clinical trials required by the U.S. Food and Drug Administration. Not good.

Over the course of the multimillion-dollar tests and trials, however, researchers outside Merck observed a curious digestive detail signaling medical potential. The scientists noticed that ailing lab ferrets—yes, ferrets; they're the new rats—ingesting the Substance P blocker vomited much less than expected. Ferret vomit thus became the leading indicator that Merck's new compound enjoyed an unexpected effect on the brain. The drug apparently blocked neuroreceptors located in regions associated with both emotion and nausea—failing on the emotional front but helping curtail vomiting.

Even as Merck feared the drug would fail as an antidepressant, the ferret results held the promise that the compound could be the basis for an antinausea drug for humans. This proved a good bet. Merck won approval for Emend in 2003 as an antinausea/antivomiting medication for patients enduring chemotherapy. No, Emend is not a billion-dollar blockbuster. But it might well be a better-than-niche business for a patient population that drug companies consider a growing market—those craving sanctuary from the wrenching side effects of cancer therapy.

Mere serendipity? That's the lazy rationale of least resistance. The better explanation simultaneously upgrades and inverts Pasteur's famous aphorism "Chance favors the prepared mind."

Data once dismissed as chaotic noise is now understood to contain meaningful signals.

Indeed it does. But now more than ever, "The prepared mind favors chance."

That's not mere wordplay. It's the essence of a new generation of data-driven strategic innovation. It's no longer enough for innovators to be sensitive to potentially provocative correlations; today's innovators must explicitly generate them en masse. While spotting ferrets that weren't puking their little guts out may seem like a case of pure luck, the reality is profoundly different: capital-intensive innovators like Merck increasingly structure their research initiatives to ensure that such startling correlations trigger recognition and review.

The discontinuity emerges from the vast breadth and scope of data that a Merck, a GE, an Airbus, a Wal-Mart, or a GM can reliably generate. There's an extraordinary clash and convergence of opportunity and intent. On the one hand, innovators are seeking laserlike precision in the focus and specificity of their innovation initiatives. On the other, it's become so cheap and easy to collect data on every aspect of an experiment's progress that the question has become, Why not? Data diversity that would once have been dismissed as chaotic noise is now understood to contain meaningful signals. Correlation becomes the crucible for innovation and insight.

The ongoing explosion in genomic and proteomic sequencing, for example, guarantees that the Mercks, Pfizers, and GlaxoSmithKlines of 2014 will be exploring statistical correlates in dataspheres better measured in exabytes than in gigabytes. A simple mutation in a bacterial colony may prove as medically significant as a nauseous ferret. This is a tale of data-driven scale.

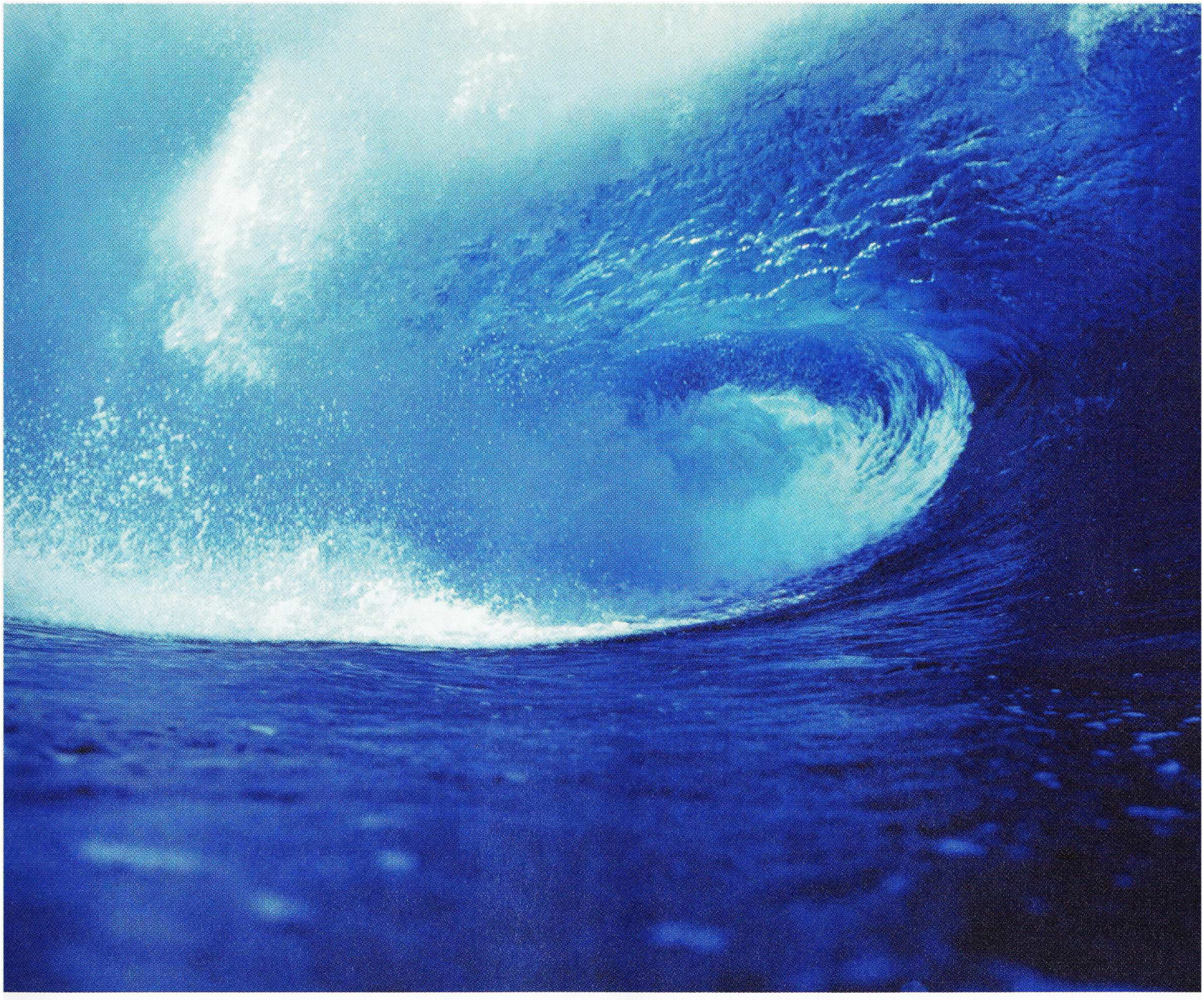
So Merck and Wal-Mart won't merely explore provocative correlations; they'll be exploring the provocative correlations of correlations. These meta-analyses will become how prepared minds cultivate chance as well as exploit it. Innovators will spend less time designing clever experiments to generate data and more time scouring the data to generate hypotheses.

Exploring correlation and causality between multiple monitoring modes should spawn even greater opportunities. We won't be measuring ferret nausea as a function of vomit; we'll be giving those rodents hourly positron emission scans to see how nausea manifests itself inside their brains. Organizations like GE's aircraft engines division already rely upon these kinds of data-driven techniques to optimize their products and processes *(see "If It Ain't Broke, Fix It," TR September 2001)*.

Of course, correlation isn't causality. Remember: there are lies, damned lies, and statistics. Then again, the economics of exploring correlation for innovation are irresistibly tempting.

The future of innovation will increasingly be determined by the future of data-driven statistical techniques. The future of data-driven statistical techniques, however, depends on innovators who grasp that ferret vomit can be a source of inspiration. That's not lucky serendipity; that's good design. TR

A researcher and consultant on innovation economics, Michael Schrage is the author of *Serious Play* (Harvard Business School Press, 2000).



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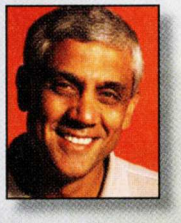

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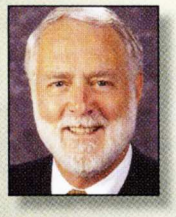

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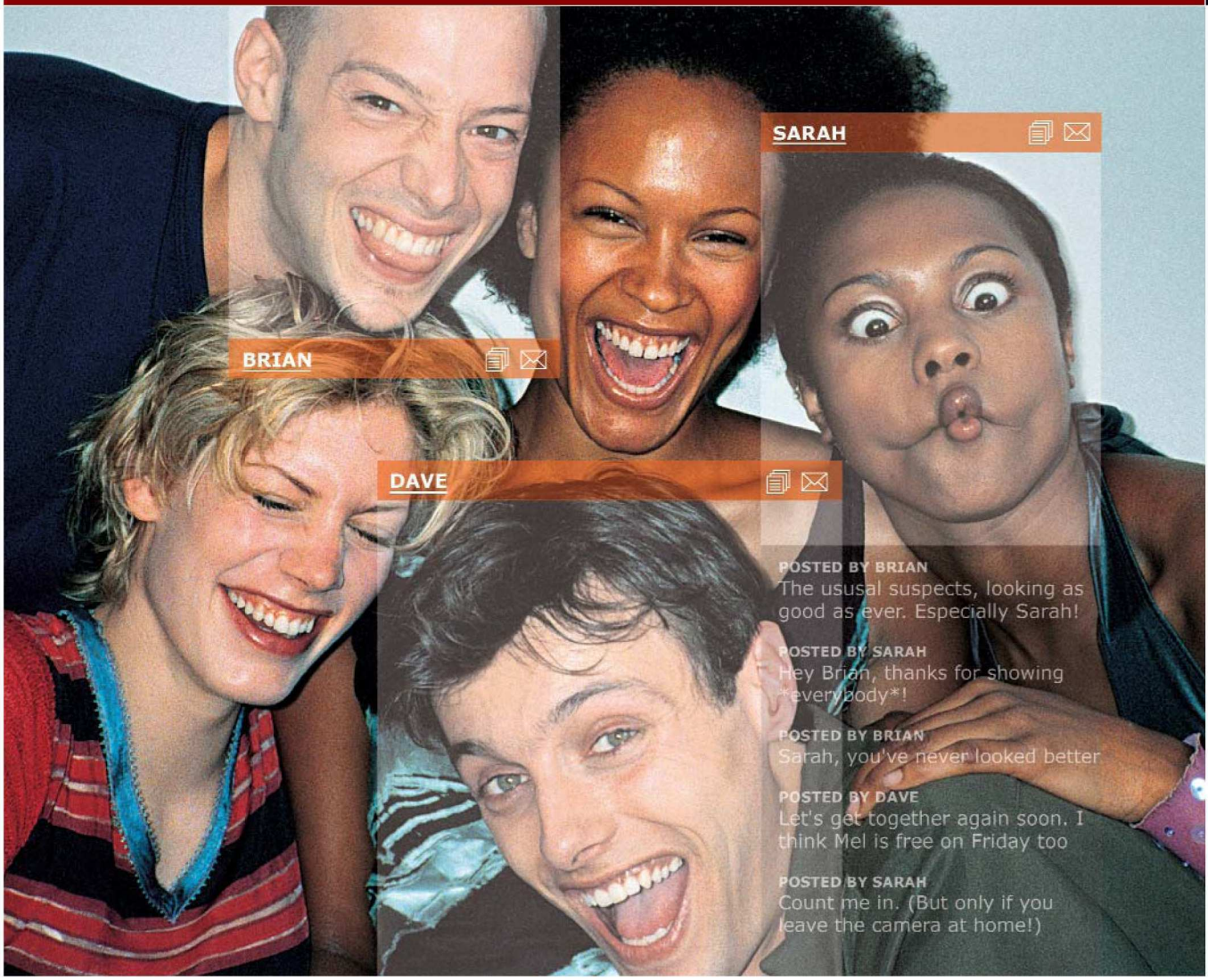


A Picture Worth 1,000 E-Mails

Photo sharing emerges as one of the fastest-growing Web applications. **BY WADE ROUSH**

The Internet already swirls with millions of images created by consumers using digital cameras. And by the end of 2004, some 180 million cell phones worldwide will have cameras built in, according to InfoTrends/CAP Ventures, an analysis firm in Weymouth, MA. So it's not surprising that one of the fastest-growing Internet applications is online photo sharing: the creation of individual or group Web albums where people can upload digital snapshots and invite friends to view and comment on them or order prints.

Not only is it becoming one of the hottest uses of the Web, but it's also driving a booming business in the sale of website memberships and photo prints. Compared to overall e-commerce revenues, which reached some $54.9 billion last year, earnings at commercial photo-sharing sites in North America are still small, totaling $124 million in the same period; but they're set to increase to $206 million this year, says Jill Aldort, a senior research analyst at InfoTrends. And several companies, including Microsoft, are introducing technologies intended to turn photo sharing into the basis for supercharged social-computing experiences, meaning everything from

DIGITAL VISION

photo-enhanced instant messaging to community organizing and networking.

Commercial photo-sharing websites where users can create online photo albums and order prints have been around almost as long as the Web; the names most familiar to consumers today are Ofoto, Shutterfly, Snapfish, and PhotoWorks. A few years ago, Internet users invented a more community-based alternative, the photo Web log. One example is Fotolog.net—a popular "photoblog" that has accumulated some 345,000 members since its founding in 2002. Basic membership is free, but a $5-a-month subscription allows members to upload more photos per day, and during peak hours. "Nowadays people are carrying around cameras in their pockets and briefcases and purses," says CEO Adam Seifer. "They're going, 'Look at that graffiti or that shadow on the wall,' or 'That's the craziest dog I've ever seen,' or 'That sign is misspelled.' What do they do with these photos? There were tools like Ofoto and Shutterfly for reprints, but those aren't as satisfying as an interactive experience with other human beings. When people participate in [Fotolog], they become part of something bigger than just themselves."

Companies are launching technologies that will turn photo sharing into supercharged social-computing experiences.

But Fotolog's content is static: users must check in periodically to see what others have said about their photos. At Vancouver, British Columbia-based Ludicorp, programmers have made it easy to share photos during real-time conversations. Flickr.com, launched by Ludicorp in February, lets users upload photos to personal "shoeboxes," set up group instant-messaging conferences with their friends, tag all or parts of a photo with personal notes, and intersperse their text-based conversations with images simply by dragging photos from their shoeboxes to the messaging window. As with Fotolog, basic membership in Flickr is free, but the company plans to introduce subscription-only "pro" accounts offering more storage.

And now, in perhaps the ultimate confirmation that photo sharing is a hot trend, the world's largest software company is getting into the act. At Microsoft Research in Redmond, WA, researchers in the company's social-computing group are working on a program code-named Wallop. It offers most of the features of Fotolog and Flickr but takes the idea of photo-as-conversation-starter several steps further.

For example, when a user adds a personal note to a photo—say, a wry comment on a photo of a tipsy coworker at the company picnic—a notice about the comment is automatically e-mailed to the people on the user's friends list or to an extended network of contacts. The program follows the ensuing thread of e-mail conversation and lets users display graphical depictions of their social networks so they can see who's online and who has added comments recently. Wallop members will eventually be able to share music files and videos as well, says Sean Kelly, a software developer in the Microsoft group.

About 150 volunteers are trying the software, including a group of Puget Sound paragliders who use the service to share and discuss photos of their latest outings. If the researchers can figure out how to support thousands of simultaneous users, a much larger trial may get under way later this year. But despite all the programming work going into Wallop, it "isn't necessarily a technology project at all," says Kelly. "It's more about how these groups of friends are evolving and what kind of technology they are going to need in the future, and how the Web and multimedia can all play a part."

It's unclear how soon Wallop, or parts of it, might be folded into fully supported Microsoft products such as MSN. But whatever the timetable, Wallop represents one of Microsoft's biggest precommercial forays into social computing. "I would think that any type of photo-sharing program that they introduce—particularly if it's part of Windows or MSN—is going to be successful," says InfoTrends' Aldort.

At bottom, projects like Wallop and Flickr are a response to the emergence of a generation of people for whom computing is primarily a way to create and strengthen social ties. In Japan, the United States, and Canada, for example, gadget-crazy consumers are using their cell phones, laptops, digital cameras, camera phones, and wireless Internet connections to keep in near-constant touch with their friends and colleagues. "There's a sense that you are carrying your social relations around with you in your pocket," says Mizuko Ito, a University of Southern California anthropologist who studies cell-phone use in Japan. Photo-sharing sites are becoming both an archive and a launching point for such interactions. And for Internet users—not to mention software and device makers—that adds up to a very pretty picture.

SALES SNAPSHOT

Digital cameras shipped in North America. Actual or projected figures, in millions. Red shading indicates camera phones.

SOURCE: INFOTRENDS/CAP VENTURES

LETTER FROM JAPAN

Near-Term Nanotech

Japan's strategy: enhance conventional devices

In January 2000, President Bill Clinton announced the creation of a National Nanotechnology Initiative. "Just imagine," he said, "shrinking all the information at the Library of Congress into a device the size of a sugar cube." Clinton intended the initiative—whose funding the Bush administration has continually increased, requesting $982 million for fiscal 2005—to stimulate scientific progress and economic growth in the United States.

But the biggest beneficiary instead may be Japan.

To be sure, nanotechnology had long been a Japanese research interest. Sumio Iijima at NEC discovered the carbon nanotube—a molecule of extraordinary electrical properties and strength—in 1991. But Clinton's speech, according to Yoshio Bando of the National Institute for Materials Science in Tsukuba, jolted both the Japanese government and its research establishment "into realizing how important this field will be." A year after Clinton's speech, Japan began a nano initiative of its own—one that today shows every sign of taking off commercially far sooner than its progenitor in the U.S.

Whereas U.S. efforts emphasize fundamental research on breakthroughs like molecular computing, the Japanese efforts are more rooted in nearer-term technologies. In essence, the two main Japanese scientific funders—MEXT (Ministry of Education, Culture, Sports, Science, and Technology) and METI (Ministry of Economy, Trade, and Industry)—are focusing on using nanotech to enhance materials in conventional devices.

Some companies have proven eager to adopt nanotech: Nissan's X-Trail sport-utility vehicle has nanotube-reinforced bumpers, for example. Much more technically innovative is NEC's fuel-cell-powered laptop, to appear later this year. With clusters of carbon nanohorns—a variant nanotube with a horn-shaped configuration that was also discovered by Iijima—as electrodes, the fuel cells use methanol to make electricity and last as much as 10 times longer than conventional laptop batteries of the same size. NEC plans to introduce a model with a 40-hour life between methanol fill-ups next year. Similar laptops are expected from Toshiba and Hitachi, which announced in March that it had developed a fuel-cell personal digital assistant with an estimated life of five hours.

According to Louis Ross, managing director of the Global Emerging Technology Institute, Japan's concentration on existing consumer products lets it take advantage of its long tradition of excellence in materials development. In typical Japanese fashion, Ross says, companies, academic researchers, and government officials spent months hammering out the approach that they believed would best leverage Japanese expertise into commercial success. "Which means that everyone is starting off pointing in the same direction," he says. "Doing things this way is slower, but once the Japanese get going, they are very tough to beat."

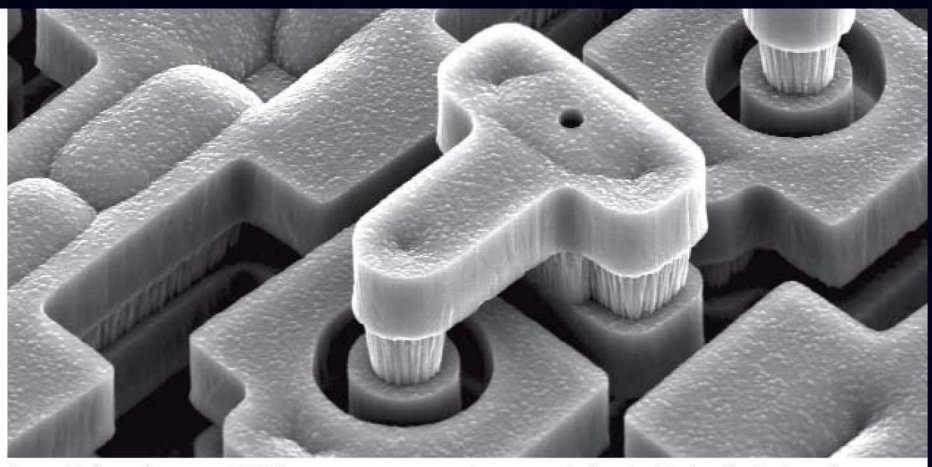
Japan's nano-research budget, some $800 million in 2003, is now second only to that of the United States. According to a December survey by Nihon Keizai Shimbun, the Japanese equivalent of Dow Jones, about one out of every three large Japanese industrial firms is working on nanotechnology R&D or planning to do so in the near future. And many of them are creating products that will go directly into the hands of consumers and businesses.

Ultrathin flat-panel displays, featherweight protective clothing, supertough automobile and airplane coatings—all are in progress in Japan. Some of the most exciting applications involve nanoglass, centerpiece of the government-industry collaboration called the Nanotechnology Glass Project. Researchers led by Hirao Kazuyuki of Kyoto University, for example, can precisely control the glass coating on DVDs, so the laser beam that plays them should be able to focus more precisely; DVDs could then be packed with more information, vastly increasing their storage capacity.

NEC used carbon nanohorns (inset) in fuel cell electrodes to provide longer life to a laptop powered by a methanol cartridge.

COURTESY OF NEC

Others are working on punching three-dimensional tracks in glass to steer beams of light. Such waveguides will act like circuit pathways in tomorrow's optical computers. According to Koji Fujita, a Kyoto nanoglass researcher, these new materials "are close to being produced" on an industrial scale. That would bring us a step nearer to fitting the contents of the Library of Congress on a device the size of a sugar cube—though they may well be preceded by the contents of the National Diet Library in Tokyo, the Japanese equivalent. **Charles Mann**



A new high-performance MEMS actuator can move mirrors or switches. In this detail, a T-shaped post just nine micrometers long is surrounded by moving parts.

COURTESY OF MEMX

HARDWARE

MEMS Blow past Air Bags

A new generation of micromachines is coming to market. So far, commercial versions of tiny sensors and actuators built on silicon chips have performed simple tasks such as switching telecommunication signals on and off or triggering air bag deployment. The next wave of microelectromechanical systems—or MEMS—however, should bring devices that perform a broader range of tasks cheaply and efficiently. MEMX, a spinoff of Sandia National Laboratories in Albuquerque, NM, is commercializing advanced versions of the technology in products that could transform everything from eye surgery to cell-phone reception.

The key to these new applications is a sophisticated yet affordable fabrication process that stacks five layers of 2.5-micrometer-thick films onto chips with tremendous precision. The extra layers of tiny sensors, gears, and electronics—most commercial MEMS devices have only two or three layers—enable not only more complex machines but also more flexibility in product design. "It's utterly amazing what they can build," says Terry Turpin, chief scientist of Columbia, MD-based Essex, a leading optical-communications company. Says Turpin, who has worked on optics for 35 years, "It's the most sophisticated MEMS stuff I have ever seen."

That sophistication could soon go to work in your mobile phone. MEMX has developed tunable cell-phone components that sense signal fluctuations caused by changing weather conditions and distances to cellular towers and can automatically adjust a phone's circuits to compensate. That will mean fewer dropped calls, better sound quality, and longer battery life. MEMX is also building movable arrays of mirrors that will let patients preview the effects of certain eye surgeries by looking through an eyepiece. The arrays work by precisely filtering the light that interacts with the cornea on the basis of computer models of the surgery.

MEMX is working with various corporate partners to commercialize the products soon, says Paul McWhorter, the company's cofounder and chief technology officer. Expect to see cell phones with the tunable components on the market in 18 months and the first eye surgery simulators in two years. With the support of large investors like Agilent and recent grants from the U.S. government, MEMX is also working on farther-out products like micro surgical tools and implantable biodevices for automatic drug delivery.

Since 2000, the year MEMX was founded, a number of other MEMS companies that targeted specific industries, such as telecom, have folded. Now, wider-scale commercialization of microdevices promises to open new markets and allow the technology to "mature in the field," says Al Romig, a vice president and former chief technology officer at Sandia. That could put this new class of tiny machines to work in your life. **Gregory T. Huang**

WIRELESS

Wi-Fi Goes to Town

Garbage collection. Police protection. And now Wi-Fi access. A growing number of towns and cities are starting to provide free high-speed wireless Internet access in parks and downtown areas. St. Cloud, FL, a suburb of Orlando, is one of the latest on the free-Wi-Fi bandwagon. Starting this summer, eight blocks in downtown St. Cloud will have coverage. And by early next year, a newly constructed, 2.4-square-kilometer business and residential development will open with free Wi-Fi. "This is a great service that we as a city should provide, like all other services like electricity, water, trash pickup," says Glenn Sangiovanni, St. Cloud's mayor, who says many residents either can't get or can't afford broadband in their homes.

Dozens of other cities around the world—from Tallahassee, FL, to Tucson, AZ, to Hamburg, Germany—are also beginning to offer Wi-Fi. And their number should soon explode, says Gerry Purdy, an analyst with MobileTrax, a Cupertino, CA, wireless-technology research firm. Between such free services and others that charge fees, "by the end of the decade, most municipal areas will either have Wi-Fi implemented or be in the process of planning it," Purdy predicts.

The new trend promises to save Internet users money in several ways. With new mobile phones coming out within the next year that can send and receive Wi-Fi signals *(see "One Person, One Phone," TR March 2004)*, users will be able to make cheap phone calls over Wi-Fi while walking around town. And commercial wireless Internet service providers will likely face pressure to cut fees, says John Yunker, an analyst with Pyramid Research in Cambridge, MA. Why pay for Wi-Fi in Starbucks when you can sip your latte and surf the Web for free in the nearby park? **Corie Lok**

ENERGY

Fuel Cells Hit Home

Japan promotes first mass use in residences

A fuel cell outside a Tokyo home sits next to tanks of natural gas.

Fuel cells are poised for their first commercial home installations. By early next year, Tokyo Gas will install the technology outside 50 Japanese homes, with plans to install 900 more units by 2007. The units will extract hydrogen from natural gas and use it to create supplemental electricity for the homes. Waste heat from the fuel cells—rather than electricity—will heat water for household use. All told, using fuel cells to reduce the homes' reliance on electricity from gas-fired power plants should cut their fossil fuel consumption by about one-quarter.

The households will be able to replace their hot-water heaters with the new fuel cell system "and also get one kilowatt of electricity for free"—enough to satisfy all the home's electricity needs during the periods of lowest demand, says Dennis Campbell, president and CEO of Ballard Power Systems in Vancouver, British Columbia, whose fuel cells are part of the Tokyo Gas system. The program will be followed by early 2006 by a similar effort from another Japanese utility, Osaka Gas.

The fuel cells are a particularly attractive option in Japan, where electricity prices are nearly double those in the United States. The fuel cell units will be pricey, though, costing consumers $3,000 to $5,000 apiece. And that's half the true cost; the Japanese government is paying the rest as part of an effort to reduce fuel consumption and carbon dioxide emissions. But because buying natural gas for the fuel cells is far cheaper than purchasing electricity, the fuel cells will pay for themselves within five to seven years, according to Campbell.

It will still be several years before fuel cell generators come down in price and achieve the reliability expected of home appliances, says Jon Slowe, research manager with Boulder, CO-based Platts Research and Consulting. Still, taking the first step of getting fuel cells into some homes "will make it easier for fuel cell technology to move forward," says Atakan Ozbek, director of energy research with ABI Research in Oyster Bay, NY. Ozbek predicts domestic fuel cells will take hold in Europe, and then the United States, within three to four years. **Corie Lok**

A HOME FOR FUEL CELLS

COMPANY	TECHNOLOGY/STATUS
Ballard Power Systems (Vancouver, British Columbia), **Tokyo Gas** (Tokyo, Japan), **Osaka Gas** (Osaka, Japan)	Fuel cells that generate electricity and heat for houses will be sold to gas customers in Tokyo and Osaka, Japan, starting in early 2005
Plug Power (Latham, NY), **Honda R&D** (Wako, Japan)	Prototype of home fuel cell unit that also generates hydrogen for fuel cell cars completed this year
Sulzer Hexis (Winterthur, Switzerland)	One hundred home fuel cells being tested in Germany, Austria, and Switzerland; commercial release planned for late 2005

DATABASES

Name That Money Launderer

One way to fight white-collar crime and thwart terror is to identify who is transferring money through banks around the world. Stiff new laws in the European Union are forcing banks to check whether funds could be linked to lists of suspected terrorists or other criminals. But the banks are often stumped by the varied spellings of names in different countries.

Now, a Virginia company that spent years developing a massive name-matching database for U.S. intelligence agencies is selling its system to help banks fight crime. The database from Language Analysis Systems of Herndon, VA, is a fundamental tool that helps reconcile myriad variations on names. And it can help determine whether someone on a watch list is the person who holds a bank account. The database contains one billion names from 200 countries and is regularly updated. But numbers alone don't do the job: "People needed better help understanding names," says Jack Hermansen, CEO of Language Analysis. Software places emphasis on different portions of names according to cultural rules. For instance, it will filter out a modifier on Arabic names that only indicates whether or not a person made a pilgrimage to Mecca, and it will disregard long common endings in Greek names. The company continually refines such strategies. By comparing only key name elements, the software finds better matches.

The first European customer is a company that helps banks fight crime. Ilogs, based in Rotkreutz, Switzerland, began deploying the system in February. Now, several banks in Switzerland and other countries are implementing the technology, which helps winnow possible matches considerably. "By using this software, our customers can reduce 90 to 95 percent of the false positives," says Felix Tausch, head of marketing for iLogs. And that's good news for banks—and crime-fighters. **Patric Hadenius**

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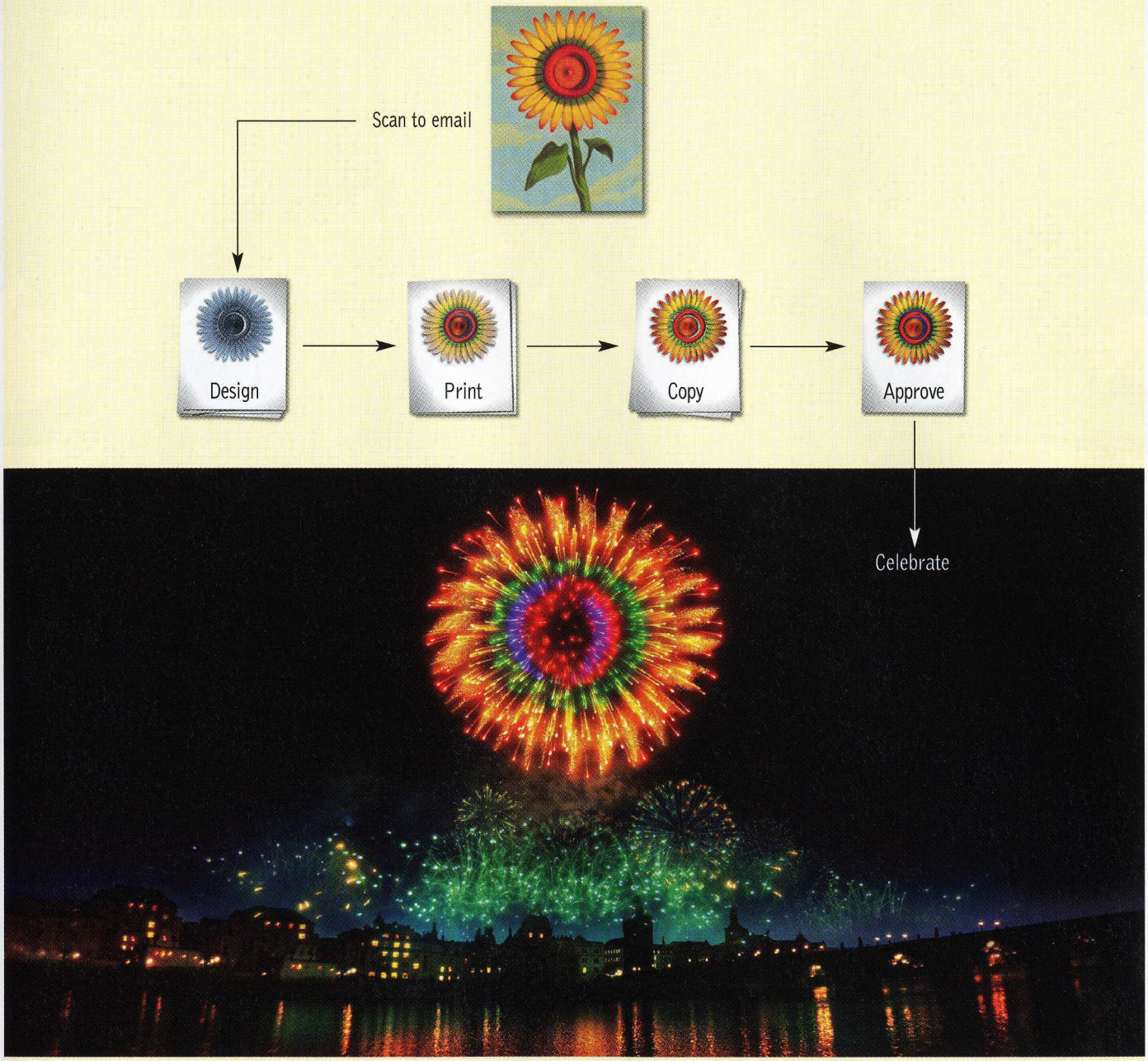

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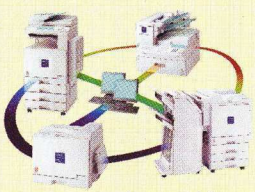

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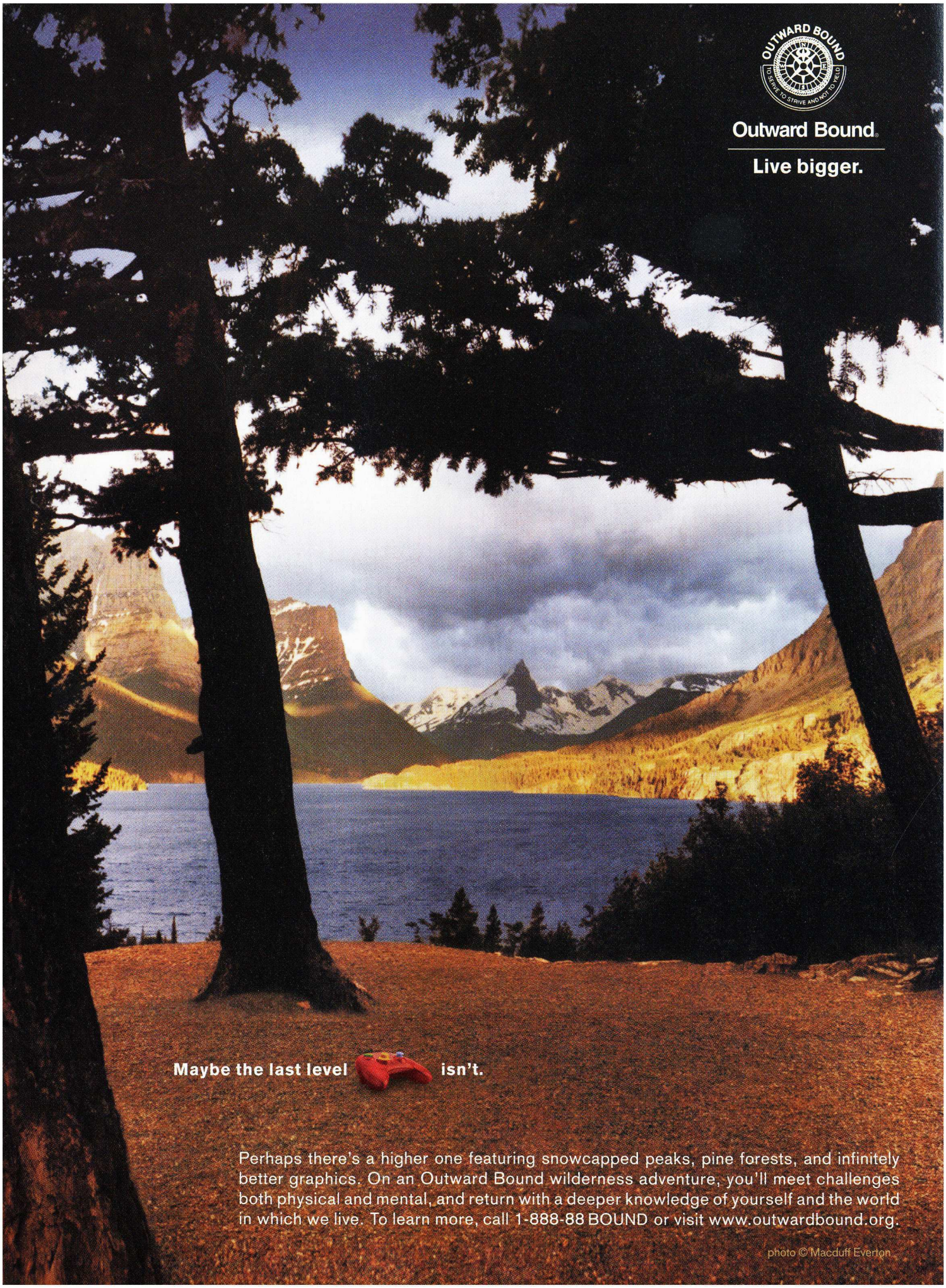
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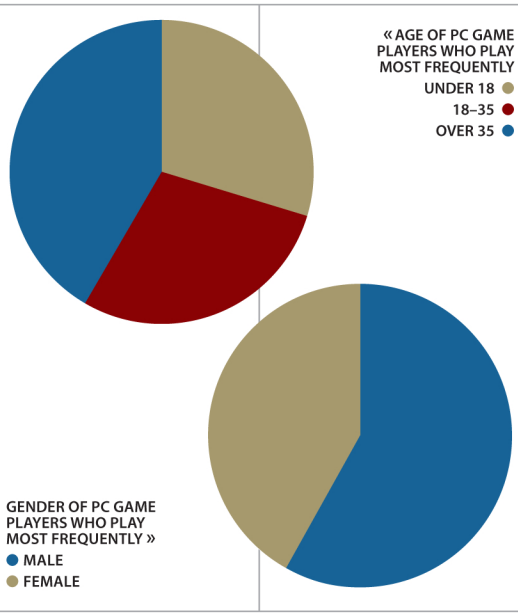
financing

Ping Identity of Denver, CO, which is trying to develop a standard to sort out the mess of multiple usernames and passwords PC users must remember, has closed a $5.8 million first-round financing deal. The deal, with Fidelity Ventures, General Catalyst Partners, and several private investors, will help fund Ping's work on software that gives each corporate employee a single username and password for all of the shared networks and programs he or she may use.

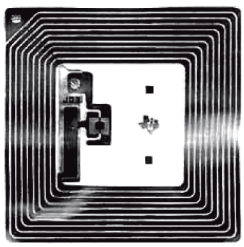


«metric

Computer games aren't just for adolescent boys anymore, according to a survey of U.S. households by the Entertainment Software Association.

ipo

Everyone knows that **Google** is going public, but some may be surprised just how candidly the search company has laid out the risks to investors. In documents filed with the U.S. Securities and Exchange Commission, Google notes that competitors may come up with better search technologies, that the loss of the company's top leaders could "seriously harm" business, and that the IPO itself could create disparities of wealth among Google employees that "may adversely impact relations."



«standards

The **Electronic Product Code** (EPC), a more information-packed successor to the traditional bar code, has gained a big supporter: Microsoft. The Seattle giant recently joined EPCglobal, a consortium backing the technology. If EPC codes—carried on radio frequency identification tags (left)—are widely adopted, they could become essential to electronic inventory-tracking systems, a market that Microsoft hopes its software will dominate.

acquisition

Xerox has sold its controlling share in digital-rights-management company **ContentGuard** to Time Warner and Microsoft for an undisclosed amount. ContentGuard, a 2000 Xerox spinoff, is the creator of the Extensible Rights Markup Language, which has become an international standard for describing how digital files such as movies or e-books can be used.

milestone

Researchers in Sweden smashed through previous Internet speed records on April 14, using Sprint's network and a high-speed university network in Sweden to send 840 gigabytes of data from **Luleå University of Technology** near the Arctic Circle to a Sprint office in San Jose, CA, in less than 30 minutes. That's the equivalent of about 200 DVD movies, and it's 12 percent faster than the previous record, set last November by a team at Caltech and the European Organization for Nuclear Research.

advance

Being close to a Wi-Fi transmitter is heaven for laptop users, but being close to several is something else entirely. In buildings with dozens of Wi-Fi transmitters, signals can overlap and interfere with each other, slowing data transmission. But **Propagate Networks** in Acton, MA, is introducing so-called swarm logic software that lets access points communicate with each other and choose nonconflicting frequencies or adjust their power levels to eliminate overlap.

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New Technologies » New Therapies » New Economics

October 18-20, 2004

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Chairman, Thoracic and
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Siemens Medical Solutions

Uwe Reinhardt, Ph.D.
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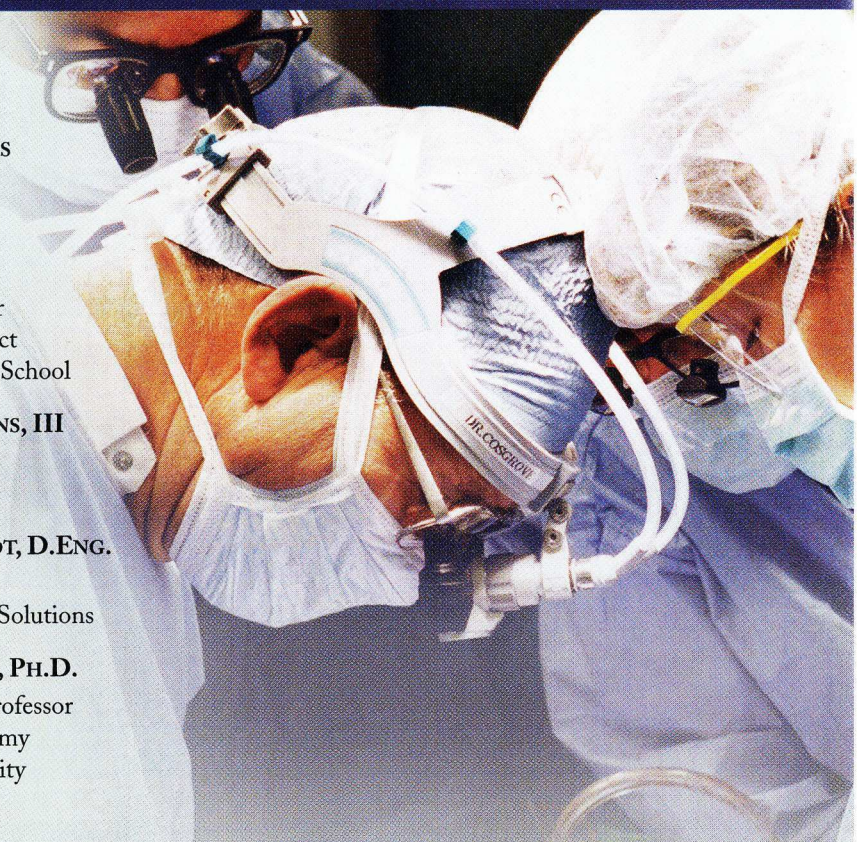
Princeton University



Join more than 800 industry leaders for the 2004 Cleveland Clinic Medical Innovation Summit, October 18–20. More than a dozen CEOs, investors and clinicians will highlight new technologies, therapies and related economics in the unique setting of The Cleveland Clinic — a world leader in patient care and medical innovation.

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The Cleveland Clinic

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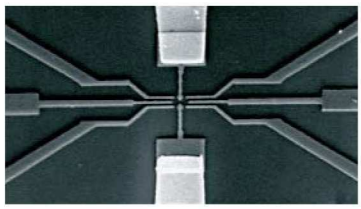


«advance

Researchers at **Purdue** and **Duke Universities** report taking a promising step toward quantum computers by linking tiny "puddles" containing 40 to 50 electrons to form part of a transistor (left). Each puddle of electrons measures only about 180 nanometers in diameter. In general, quantum computers could be extremely efficient at encryption and data searching.

Nanot

metric

Merrill Lynch has created an index of selected public companies to chart the progress of the fledgling nanotech industry on Wall Street. Merrill Lynch says it chose companies that have "a significant portion of their future profits tied to nanotechnology." The index does not include diversified corporations such as IBM and GE that are working on nanotech.

collaboration

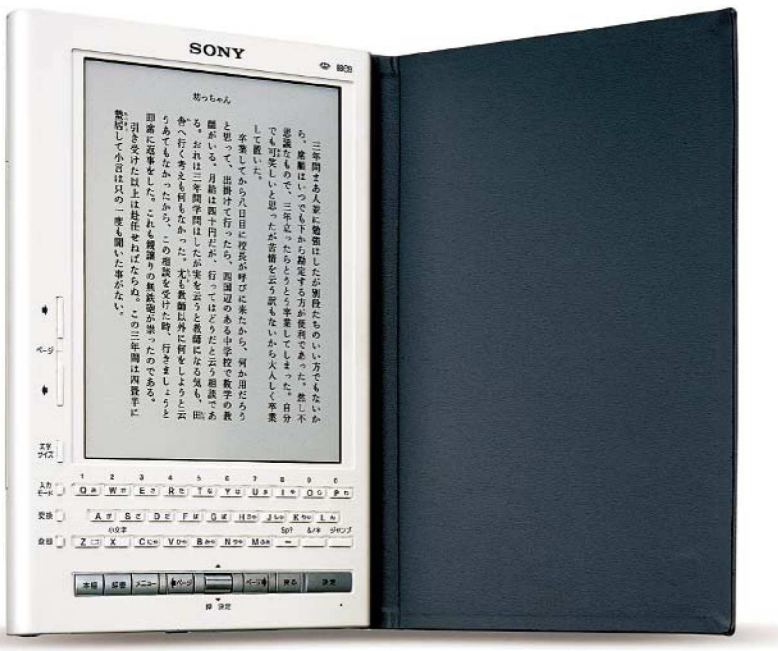
IBM and **Stanford University** are forming a research center to focus on spintronics, a field that aims to exploit the spin of electrons to create high-performance, low-power electronics. Spintronics is already used in hard drives, but IBM says it hopes to eventually deploy the technology in new types of logic devices and even quantum computers.

follow-up

Nanosys, in Palo Alto, CA, has filed papers with the U.S. Securities and Exchange Commission for an initial public offering. Nanosys is working on nanoelectronics and solar cells based on nanomaterials *(see "Nanotech's First Blockbusters?" TR March 2004)*. In the papers filed with the SEC, Nanosys stated it lost approximately $17.0 million between its founding in 2001 and 2003, and that it does not anticipate that its first products "will be commercially available for at least several years, if at all." It also notes it has collaborations with DuPont, Intel, and Matsushita Electric Works.

financ-ing

Nanotech startup **Ntera**, based in Dublin, Ireland, has raised another $9.5 million, increasing its total investment to $30 million. The new funding was led by **Doughty Hanson Technology Ventures**. Ntera is looking to commercialize displays that use nanotechnology. The company says the new investment will allow it to expand its manufacturing in Taiwan and Ireland and roll out new products for applications ranging from handhelds to large-scale public clocks.



milestone

E Ink, Philips Electronics, and Sony have jointly announced the world's first consumer product based on electronic paper. The product, a **Sony e-book** reader (above) that can store up to 500 downloadable books, went on sale in Japan this spring. Its display uses E Ink's technology, which employs tiny microcapsules that act as electronically responsive ink *(see "Dazzling Display," TR March 2004)*.

COURTESY OF E INK (MILESTONE); ALBERT CHANG/DUKE UNIVERSITY DEPARTMENT OF PHYSICS (ADVANCE)

Congratulations

The Lemelson-MIT Awards for Invention and Innovation

2004

LEMELSON-MIT PROGRAM

Nick Holonyak, Jr.

$500,000 Lemelson-MIT Prize Recipient

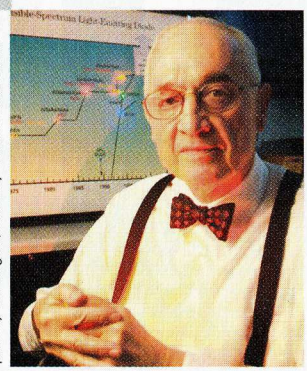


photo by Bill Wiegand, University of Illinois News Bureau

A pioneer in semiconductor laser technology, Nick Holonyak, Jr. has had a profound influence on the lighting industry, global communications and consumer products. Inventor of the first practical red LED (light emitting diode) in 1962, he also developed semiconductor lasers adapted for use in CDs, DVDs, and global fiber optic communications systems.

Edith Flanigen

$100,000 Lemelson-MIT Lifetime Achievement Award Recipient

photo by Lee Balgemann

Edith Flanigen's groundbreaking work in chemistry and materials science over the past four decades has helped make petroleum refining cleaner, safer, and more efficient. While working as a research chemist at Union Carbide, she led a team that uncovered a new generation of synthetic molecular sieve zeolites, widely used in the chemical, petrochemical and petroleum refining industries.

Call for Nominations

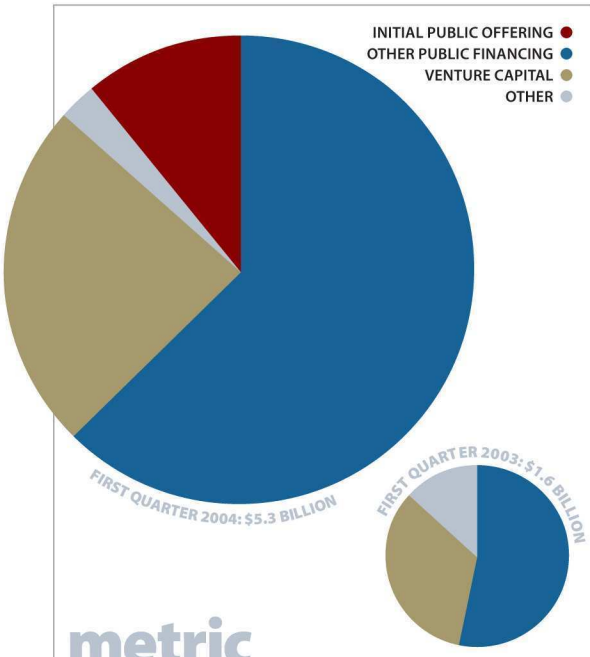
The deadline for nominations for the 2005 awards is October 7, 2004.

For further details or a nomination packet, visit http://mit.edu/invent/a-main.html, or contact Michael McNally at 617.253.3490 or mmcnally@mit.edu.

For more information on the Lemelson-MIT Program and its award winners, visit:

http://mit.edu/invent

MIT



metric

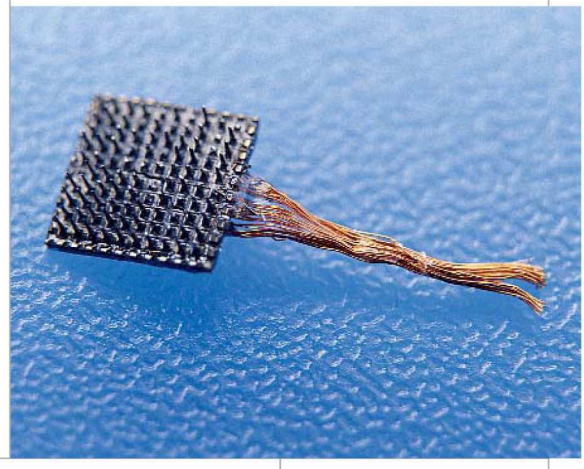
The **biotech industry** started off the year with one of its best financing quarters ever, according to a report from Burrill and Company.

ipo

Montvale, NJ's **Memory Pharmaceuticals** made its debut on the Nasdaq national market in April, with an initial public offering that raised some $35 million in the first day. The company, whose cofounders include Nobel laureates Eric Kandel and Walter Gilbert, is aiming to build on Kandel's work on the biology of memory to develop treatments for central-nervous-system disorders such as Alzheimer's disease, schizophrenia, and age-related memory loss.

milestone

The U.S. Food and Drug Administration has given Foxborough, MA-based startup **Cyberkinetics** the green light to begin human tests of its "brain-machine interface" device *(see "Brain Power," TR April 2002)*. The device, a four-millimeter-square array of 100 tiny electrodes (below) that will be implanted in the brains of up to five quadriplegic people and connected by wires to a nearby computer, promises to let the patients control the computer—and associated communication tools and other aids—using only their brain signals.



Biote

follow-up

Cambridge, MA-based startup **Alnylam Pharmaceuticals** filed preliminary papers with the U.S. Securities and Exchange Commission for an initial public offering. Alnylam is one of a handful of companies that have sprung up in recent years around RNA interference (RNAi), in which small pieces of RNA are used to turn specific genes off—to block the progress of a disease, for example *(see "The RNA Cure?" TR November 2003)*. Alnylam's aim is to develop RNAi therapeutics for ailments such as age-related macular degeneration, a leading cause of vision loss in older people, and Parkinson's disease.

advance

A new vaccine might succeed where cigarette-pack warning labels have failed. **Nabi Biopharmaceuticals** of Rockville, MD, has completed early human tests of a vaccine aimed at preventing nicotine addiction and helping hooked smokers quit. The trial proved the ability of the vaccine to generate antibodies against nicotine; further tests planned to conclude in the second half of this year will measure the vaccine's ability to help smokers kick the habit.

acquisition

In a stock deal worth $9.5 billion, Fairfield, CT-based **General Electric** has acquired **Amersham**, a British medical-diagnostics and life sciences firm. Among the benefits that GE executives expect: faster development of molecular imaging and personalized medicine.

forecast

The nonprofit **International Service for the Acquisition of Agri-Biotech Applications** (ISAAA) predicts that, despite debate, genetically modified crops will blossom. The ISAAA projects the crops' global market value to reach $5 billion by next year; within the next five years, it predicts, 10 million farmers in at least 25 countries will plant 100 million hectares of biotech crops.

FURNALD/GRAY

99 Percent

IF GENIUS IS 99 PERCENT PERSPIRATION (AND 1 percent inspiration), then entrepreneurs surely walk the fine line that separates the Einsteins of the world from those poor sweaty souls who practice yoga in saunas. The archetypal startup is the lone inventor in a basement pursuing his or her passion with relentless energy. Somewhere between the original spark of genius and a successfully profitable enterprise, though, lies a maturation process that pits the inventor's vision against the cold and cynical outlook of the business world. Often the 1 percent—a deep and highly individual creative desire—gets lost amid the desire to look and feel like a "real" company. But it is quirky proclivities combined with the sweat that creates the innovations around which successful businesses are formed.

Maggie Orth, founder, president, and sole employee of International Fashion Machines, may not yet qualify as a genius (such labels being generally applied retrospectively), but she certainly has expended the kind of obsessive effort that would make Dr. Einstein proud. Orth creates what she calls interactive textiles—fabrics with technology literally woven in—that can do things such as change color, broadcast and receive radio signals, or act as keyboards under one's fingertips.

Many regard the seamless weaving of technology into our personal environments as an inevitable trend with huge profit potential (witness the dramatic expansion of wireless networking, for one), and Orth is no exception. She believes integrating electronics into the clothes we wear, the fabrics we sit on, and the materials that clad our walls is the next logical step.

Yet one look at Orth's interactive fabrics, and it's obvious that she is driven by far more than a desire to capitalize on a hot trend. Simply put, her pieces are stunningly beautiful. Her "electric plaid" fabrics, for instance, are intricately woven with fibers that shift colors when heated via electronic controls. The result is a sublimely animated, vividly colored wall covering that is constantly in motion.

SCORECARD: INTERNATIONAL FASHION MACHINES

ELEVATOR PITCH	Textiles that weave information into our lives
FUTURE VISION	Technology as part of everything we see, touch, and wear
CEO'S INSOMNIA	Products relegated to the "gadget" shelves
LEG UP	Obsessive experience with a tricky technology, plus patents

The strong aesthetics of Orth's creations are no surprise: she trained as an artist at the Rhode Island School of Design before earning a PhD at MIT's Media Lab. "The problem I had when I got to MIT is that I couldn't make beautiful things out of technology," she says. Orth quickly solved that problem, creating, among other items, a jacket with a built-in musical synthesizer played via an embroidered keypad and an haute-couture "firefly" evening gown with integral lighting that sparkled and flashed as the wearer walked.

Like many 99 percenters, Orth can trace her drives to childhood. "The sewing machine I still use is the one my mother taught me to sew on when I was four. It's like a part of my body," she says. But for her, as for any entrepreneur, the critical existential issue is revenue, so Orth is readying a new line of consumer products that she hopes will start bringing interactive textiles into the mainstream. Her first product is a light switch that works like an ordinary dimmer but is faced by her electrically active fabric instead of a chunk of plastic. Another switch is controlled by patting a conductive pom-pom that looks as if it were plucked from a child's sock.

Orth sees the switches and similar consumer devices as important steps, not just for their anticipated commercial success, but as a way to establish interactive textiles' safety. Orth hopes the products earn "UL listings," which designate that a device has been tested and deemed safe by the nonprofit Underwriters Laboratories. Existing safety codes for textiles and electronics weren't created with woven circuitry in mind, and Orth faces an uphill battle educating standards boards.

Nonetheless, Orth sees that challenge as part of her artistic vision. "I think it's actually a bit perverse to be selling a UL-listed pom-pom," she laughs. "Textiles are incredibly intimate and tactile, and weaving technology into our intimate spaces changes the way we live." When described that way, Orth's aesthetically driven approach starts to make a great deal of commercial sense. "You can't just dump information and technology into people's personal spaces. It has to be beautiful or people won't want it," she says.

Orth's stewardship of her company shows remarkable resourcefulness and care. She's raised (and spent) only about $100,000 in investment so far, and while her sales figures are still small—she's sold a few specialty wall hangings—her reputation brought her research contracts from DuPont and the U.S. Department of Defense. Orth is now seeking further angel capital to produce and market her consumer products, which she hopes to sell through stores like the Sharper Image.

International Fashion Machines faces a long road to commercial success. But if someday, as Orth would have it, your communication system is woven into your T-shirt, you can regale your kids with stories of how phones used to be easily misplaced lumps of plastic. And perhaps your shirt, when the perspiration threshold crosses that 99 percent mark, can reach out invisibly and turn down the heat.

Joe Chung cofounded Cambridge, MA-based Art Technology Group. Neither he nor *TR* holds any financial interest in the companies profiled nor endorses them as investments. To share your company's story with Joe, e-mail joe.chung@technologyreview.com.

Endless energy: Konarka's solar cells (red) on flexible plastic convert sunlight into electricity over large areas.

SOLAR-CELL ROLLOUT

Cheap, flexible solar cells could help avert the world's impending energy crisis. That's a big promise. But a handful of startups and established companies are vying to make good on it, by developing printable devices made of plastics and nanomaterials.

BY PETER FAIRLEY PHOTOGRAPHS BY KATHLEEN DOOHER

ON THE TEST BENCHES OF KONARKA TECHNOLOGIES IN LOWELL, MA, A NEW KIND OF SOLAR CELL IS BEING PUT THROUGH ITS PACES.

Strips of flexible plastic all but indistinguishable from photographic film bask under high-intensity lights. These strips, about 10 centimeters long and five centimeters wide, are converting the light into electricity. Wire a few of them together, and they generate enough power to run a small fan.

Solar cells, of course, are nothing new. But until now, solar power has required expensive silicon-based panels that have relegated it, largely, to niche applications like satellites and high-end homes. What's remarkable about Konarka's power-producing films is that they are cheap and easy to make, using a production line of coating machines and rollers. The process is more akin to the quick-and-dirty workings of a modern printing press than to the arcane rituals performed in the clean rooms of silicon solar-panel manufacturing. The company literally has rolls of the stuff; its engineers plan to cut off usable sheets as if it were saran wrap.

Konarka's technology is just one example of a new type of printable solar cell, or photovoltaic, that promises to go almost anywhere, paving the way for affordable and ubiquitous solar power. Not only are the cells inexpensive to produce—less than half the cost of conventional panels, for the same amount of power—but they're also lightweight and flexible, so they can be built into all sorts of surfaces. Flexible films laminated onto laptops and cell phones could provide a steady trickle of electricity, reducing the need to plug in for power. Solar cells mixed into automotive paint could allow the sun to charge the batteries of hybrid cars, reducing their need for fuel. Eventually, such solar cells could even cover buildings, providing power for the electricity grid.

A growing number of startups, like Konarka, and big corporations, such as General Electric, Siemens, and chip maker STMicroelectronics, are vying to realize this vision *(see "Printable-Solar Revolution," p. 38)*. Konarka hopes to start selling its solar films next year for use in consumer electronics and defense applications. And this winter, Siemens announced that it had boosted the power output of its own prototype plastic-based solar cell to new heights—an achievement that could finally make the technology viable for widespread use.

What's making all this possible is recent breakthroughs in materials science, including advances in nanomaterials. Some of the most promising solar devices are made from conducting plastics and nano-based particles, far too small for the eye to see, that are mixed in a solution. This solution can then be printed, in a process similar to ink-jet printing, onto a surface; there the nanomaterials assemble themselves into structures within the plastic, forming the basis of a solar cell. And all this is done with little human intervention. "The fabulous notion here is that we may be able to put this active agent in some spreadable medium and basically print these things," says Rice University chemist Richard Smalley, who shared the 1996 Nobel Prize in chemistry for the discovery of soccer-ball-shaped carbon molecules known as buckyballs, a key ingredient in many nano solar cells.

Making these cells efficient enough to compete with coal, wind, and nuclear power remains an ambitious goal, but it's one that experts say is attainable. Though mainstream applications are early-stage, "the way has been opened," says Serdar Sariciftci, a materials physicist at Johannes Kepler University in Linz, Austria, and a Konarka advisor. "The avalanche has started."

PRINTING POWER

In 2003, more conventional solar panels were manufactured than ever before, yet all of them, together, yielded just 750 megawatts of electricity—the equivalent of one average-size coal-fired power plant. What's holding up the solar industry is cost. Most top-of-the-line solar panels are made with 15-centimeter wafers of crystalline silicon, and those materials are very expensive. As a result, solar power is four to ten times more costly to produce than electricity from conventional power plants.

For decades, solar-cell researchers have tried to develop cheaper alternatives to silicon. The problem has been efficiency: other materials just don't generate enough electricity. But Siemens's achievement earlier this year of the highest efficiency to date in plastic solar cells could change that. The Siemens design combined two of the most important advances in materials science in the past 30 years: electrically conducting polymers and buckyballs.

The idea of combining these materials to capture solar power first gained credence in the early 1990s, when physicists Sariciftci and Alan Heeger at the University of California, Santa Barbara, created primitive photovoltaic devices by pouring a solution of conducting plastic and buckyballs onto a glass plate, spinning the plate to spread the solution into a film, and sandwiching the film between electrodes. The conducting polymer absorbed photons, kicking off electrons that were then attracted by the buckyballs and routed to an electrode.

PRINTABLE SOLAR CELLS COULD BE BUILT INTO THE SURFACES OF CELL PHONES, LAPTOPS, CARS, AND EVEN BUILDINGS, PAVING THE WAY FOR AFFORDABLE AND UBIQUITOUS SOLAR POWER.

In short, the film acted like a solar cell. Originally, the power output was meager (less than 1 percent of the energy of incoming sunlight). But the principle of the printable solar cell was proved: you could layer a photovoltaic material on a surface and make it work without complex preparations.

JÜRGEN HORN

Day in the sun: Christoph Brabec, Siemens's plastic-solar-cell leader

For Sariciftci, printable solar cells became an obsession. In 1996, after moving to Kepler University, Sariciftci began assembling a research team to boost the power output of his devices. One of his first recruits was Christoph Brabec, a young polymer scientist. By 2000, Sariciftci and Brabec had found a mix of solvents, temperatures, and drying conditions that delivered a better blend of plastic and buckyballs. The result: more electrons made the jump from plastic to buckyball, more than doubling the power output *(see "Solar on the Cheap," TR January/February 2002)*.

In 2001, Brabec left Sariciftci's lab to head a new research effort in polymer photovoltaics at Siemens. It was his team at Siemens that earlier this year significantly increased the power output of the buckyball-plastic cell by tweaking the nanomaterials and shifting to a more industrial-style coating method. Exactly why the power jumped is not yet clear, says Brabec, though he suspects that the explanation has to do with a more regular structuring of the cell's polymers and buckyballs. What is clear to Brabec is that he and his colleagues can squeeze even more power out of these cells, at least doubling their efficiency once more to capture 10 percent of incoming solar energy—a percentage that experts consider to be a threshold for rooftop applications. "We are absolutely sure that efficiency will continue to climb," says Brabec.

Now, he says, it is time to demonstrate that large-scale production is feasible. "What we did was in a clean room, and the maximum module size is [15 centimeters]," he explains. "The logical next step is to get out of the lab and try reel-to-reel production under industrial conditions." He hopes to get there next year.

PRINTABLE-SOLAR REVOLUTION

GENERAL ELECTRIC, Schenectady, NY
Adapting methods developed for printable lighting panels to make solar cells; pushing for 10 percent energy efficiency in a practical cell

KONARKA TECHNOLOGIES, Lowell, MA
Manufacturing solar cells made of semiconductor particles; plans to market 5 percent efficient cells by 2005

NANOSOLAR, Palo Alto, CA
Testing titanium compounds and conductive plastic that can be sprayed on surfaces to form solar cells; seeking 10 percent efficiency by late 2005

NANOSYS, Palo Alto, CA
Developing self-orienting nanoparticles in conductive plastic for photovoltaic coatings; plans to incorporate them into commercial roofing tiles in a few years

SIEMENS, Erlangen, Germany
Researching buckyballs and conductive plastic for solar cells and photodetectors; seeks practical flexible cells by 2005

STMICROELECTRONICS, Geneva, Switzerland
Blending buckyballs with carbon-based molecules containing copper atoms to make solar cells; conducting research into efficiency and feasibility

SHINING STARTUPS

At least one startup may beat Siemens to that goal. Konarka is now gearing up to manufacture its novel photovoltaic film, which it expects to start selling next year. Unlike Siemens's, Konarka's films don't use buckyballs, instead relying on tiny semiconducting particles of titanium dioxide coated with light-absorbing dyes, bathed in an electrolyte, and embedded in plastic film. But like Siemens's solar cells, Konarka's can be easily and cheaply made.

Konarka sees a short-term payoff in consumer products. Power-hungry electronics such as cell phones and laptops—and anything else with a battery and access to light—could make good use of Konarka's flexible film, according to executive vice president Daniel McGahn. And the solar films could eliminate the need to run power cords to many other electronic devices installed in homes or businesses, such as the temperature, gas, and process sensors scattered throughout manufacturing plants.

Down the road, researchers hope to boost nano solar cells' power output and make them even easier to deploy, eventually spraying them directly onto almost any surface. Palo Alto, CA-based startup Nanosolar, which has raised $5 million in venture capital, is working on making this idea practical. The company is exploiting the latest techniques for automatically assembling nanomaterials into precisely ordered architectures—all with a higher degree of control than ever before possible.

Nanosolar's approach is disarmingly simple. Researchers spray a cocktail of alcohol, surfactants (substances like those used in detergents), and titanium compounds on a metal foil. As the alcohol evaporates, the surfactant molecules bunch together into elongated tubes, erecting a molecular scaffold around which the titanium compounds gather and fuse. In just 30 seconds a block of titanium oxide bored through with holes just a few nanometers wide rises from the foil. Fill the holes with a conductive polymer, add electrodes, cover the whole block with a transparent plastic, and you have a highly efficient solar cell.

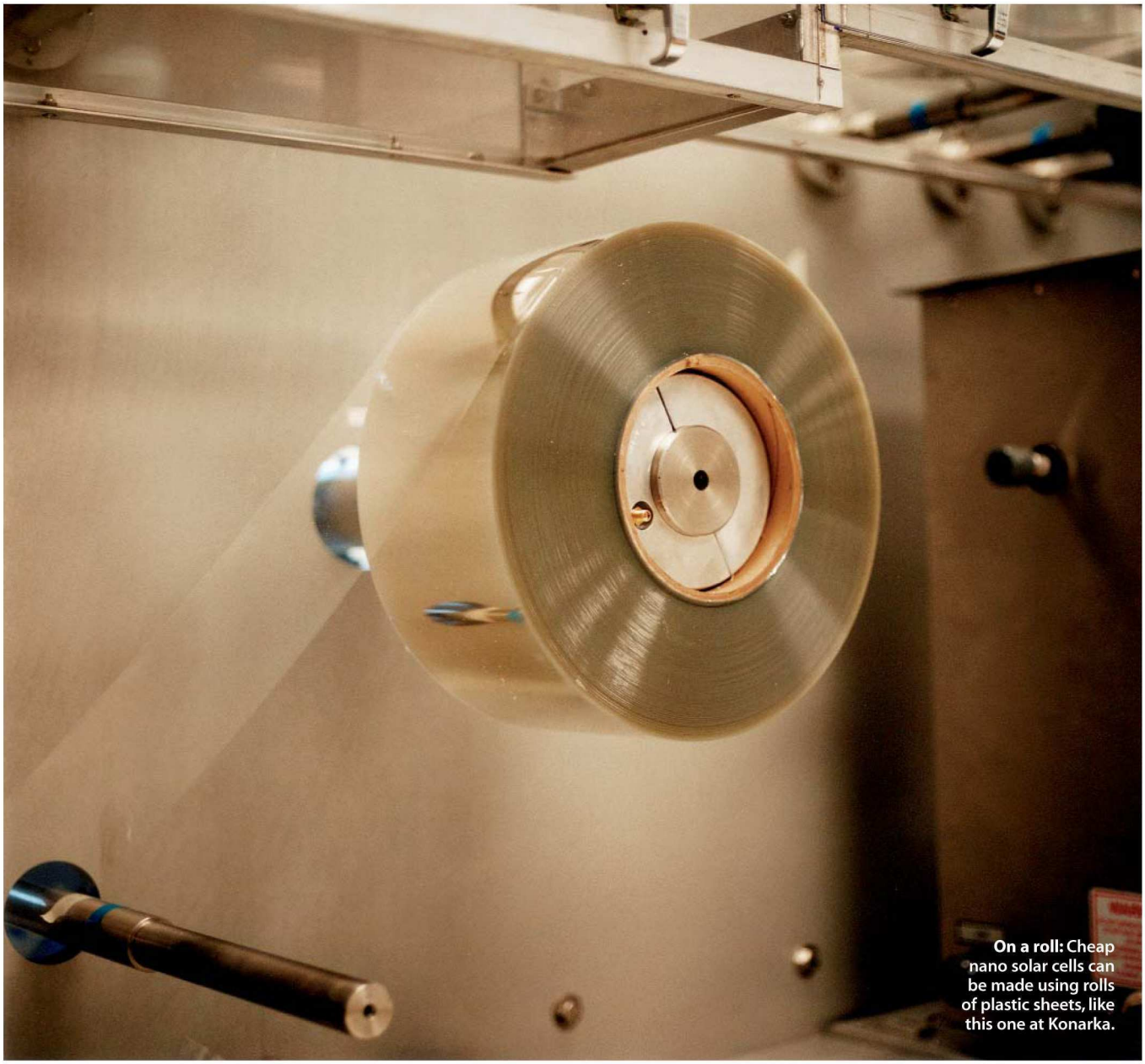
In theory, at least, energized electrons in Nanosolar's columns of plastic need only jump a few nanometers to reach the titanium compounds. From there, the electrons shoot straight through the vertically oriented titanium compounds to an electrode. "It's a fast path out," says Nanosolar's CEO Martin Roscheisen, an Internet entrepreneur who founded the company two years ago.

This technology could enable Nanosolar to spray-paint photovoltaics onto building tiles, vehicles, and billboards, and wire them up to electrodes. At first, the cells would be applied in manufacturing, but eventually they might be sprayed onto existing surfaces. When will this approach become prevalent enough to feed electricity to power grids? Roscheisen won't say, but he vows that by the end of next year, Nanosolar will have prototypes that capture 10 percent of incoming solar energy.

CATCHING SOME SUN

In their initial applications—such as powering cell phones and laptops, as Konarka envisions—printed solar cells won't need to produce that much power or run for decades at a time. But scal-

Handheld power: Konarka's solar film is light and flexible and could be laminated onto portable devices.



On a roll: Cheap nano solar cells can be made using rolls of plastic sheets, like this one at Konarka.

ing them up from personal electronics to rooftops is a whole other story.

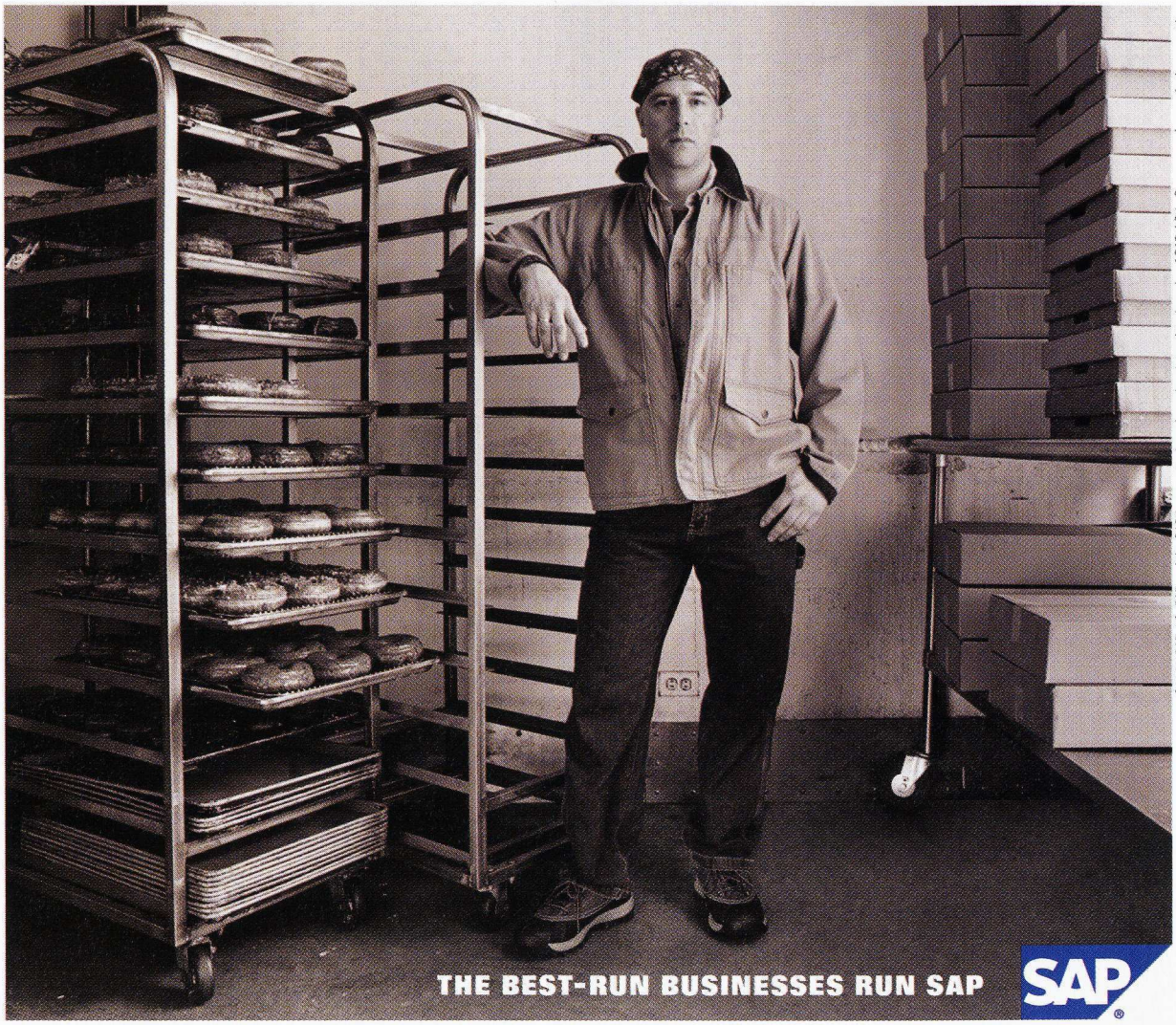
Unlike the crystalline silicon in conventional solar panels, the polymers and dyes employed in printable solar cells are exquisitely sensitive to oxygen. Protecting these materials from blowing sand, intense sunlight, extreme temperature shifts, and the myriad other forms of abuse that nature heaps on solar panels will require hermetic seals. But Brian Gregg, a solar expert at the U.S. Department of Energy's National Renewable Energy Laboratory, predicts that materials scientists will soon develop workable seals that will protect the delicate devices over the long term. "There's no reason to believe that we can't make [printed] solar cells that will last for 30 years," says Gregg.

Indeed, the recent advances in printable solar cells—and the growing possibilities presented by nanotechnology—leave many experts more optimistic than ever that the technology is nearly ready to tackle one of the world's most troubling problems: how to create a ready and renewable supply of energy. Nanotech pioneer Richard Smalley, for one, is convinced that a solar-powered grid is not just possible but also inevitable—and indispensable. Nanotech could help solve the energy problem, Smalley contends, by providing new tools and materials that make widespread use of solar cells economically viable. But he believes it will take billions of dollars in funding and the focused efforts of the world's top chemists and physicists to make that happen. So for the past two years, he has been crisscrossing the United States, evangelizing for nothing short of a modern-day Manhattan Project to use nanotech to deliver a sustainable energy system.

That's the long-term vision. In the meantime, the Konarkas and Siemenses of the world are taking some critical first steps toward changing how we think about harvesting energy from the sun, and how we use electricity in our lives. It may not yet be the Manhattan Project urged by Smalley, but it's a fast-growing effort that could quickly reach critical mass. TR

Peter Fairley, a *Technology Review* contributing writer, covers technology, energy, and the environment from Victoria, British Columbia. His last story for *TR* was "Hybrids' Rising Sun" (April 2004).

COMPANIES THAT THOUGHT THEY COULDN'T AFFORD SAP RUN SAP.



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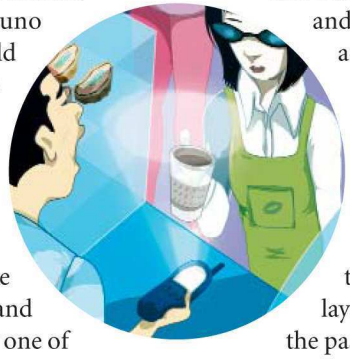
A REMOTE CONTROL FOR YOUR LIFE

BY CHARLES C. MANN ILLUSTRATIONS BY MARCOS CHIN

A CELL PHONE THAT PAYS YOUR SUBWAY FARE, GETS YOU THROUGH AIRPORT SECURITY FASTER, AND RUNS YOUR HOUSE REMOTELY? JAPAN'S NTT DOCOMO IS BUILDING IT—AND BRINGING "UBIQUITOUS COMPUTING" TO LIFE FAR AHEAD OF SCHEDULE.

TAKESHI NATSUNO WANTS YOUR WALLET. MONEY, CREDIT CARDS, DRIVER'S LICENSE, PICTURES OF JUNIOR AND SIS—THE WORKS. AND WHILE HE'S AT IT, HE'LL TAKE YOUR KEYS, YOUR BANK PASSBOOK, AND A BUNCH OF YOUR OTHER VALUABLE STUFF.

But Natsuno is no thief. He's the managing director for i-mode strategy at NTT DoCoMo, the biggest cell-phone company in Japan—and one of the most innovative telecommunications firms anywhere in the world. His title bears some explanation: "NTT" stands for Nippon Telegraph and Telephone, the former state telephone firm that owns two-thirds of his company. "DoCoMo" is a labored English acronym for "*Do Co*mmunications over the *Mo*bile Network," as well as a play on the Japanese word *dokomo*, which means "anywhere." And "i-mode" is DoCoMo's wireless Internet service—by far the world's most successful, with some 41 million subscribers in Japan alone (compared to four million for Sprint's PCS Vision, the first popular wireless data service in the United States), not to mention licensed versions in seven European nations and Taiwan. Natsuno wants your wallet because DoCoMo plans to build on i-mode to transform the cell phone into a kind of remote control for your entire life—and a preview of tomorrow's universal computing.



The plan will go into gear this summer, when DoCoMo introduces a new and radically more versatile type of phone. Like a regular cell phone, it will make and receive telephone calls. Like a regular i-mode device, it will let you send and receive e-mail, play online games, and access any one of the 78,000 i-mode-compatible websites around the world. And like other DoCoMo phones, it will take photographs, read bar codes, and play downloaded music over headphones or tiny but surprisingly good speakers. But it will also contain a special chip made by Sony that lets it pay for groceries, serve as personal identification, unlock doors, operate appliances, buy movie and subway tickets, and perform dozens of other tasks.

"All the credit cards, loyalty cards, keys, money—all that stuff in a woman's purse or a man's wallet—should go into the phone," Natsuno says. "By having the phone with you, you shouldn't need anything else but your clothes."

More than just a major advance in cell-phone technology, DoCoMo's new system is a first step toward a low-rent version of one of computer science's biggest dreams: ubiquitous computing. Coined by the late Mark Weiser of Xerox's Palo Alto Research Center in the 1980s, the term refers to the promised "third wave" in computing, in which networked computers merge seamlessly into the human environment. In the archetypal scenario for such networks, office workers' refrigerators scan themselves every afternoon to see whether they have any milk; when workers get into their cars, their phones automatically call their houses, which respond with "buy milk" reminders. Most visions of ubiquitous computing have involved either a flotilla of exotic new devices like smart refrigerators and coffee cups or an extensive retrofitting of our surroundings with sophisticated sensors and actuators.

DoCoMo, though, is taking an entirely different approach. It is cobbling together a kind of quick-and-dirty version of ubiquitous computing by adapting existing hardware and software and funneling control of the system through the cell phones its customers are already carrying in their pockets.

"'Ubiquitous computing' is one of those engineer's terms that customers don't want to know about," Natsuno says. "The words never cross my lips. But yes, that's where we are heading."

The result, he believes, will be both a glimpse of the future and a step toward spreading DoCoMo technology across the world.

LOVE AT FIRST BYTE

The scene never fails to startle visitors from the United States. A subway train stops in the station, and the public-address system announces a pause to clear some bit of detritus from the tracks. Delayed for several minutes in hyperpunctual Japan, all the passengers silently and simultaneously extract their cell phones and thumb-tap messages to whomever they are on their way to meet: *Sorry, I'm going to be a little late...*

Japan isn't the most wirelessly connected society in the world; that honor goes to Taiwan and Luxembourg, which both have 106 cell phones for every 100 inhabitants, compared to a mere 64 per 100 in Japan, according to the most recent data from the International Telecommunication Union. But the Japanese use mobile communications for more purposes than any other people. Text messaging, for example, is a strongly encouraged alternative to phones ringing and people chatting in public places, which are (rightly) considered irritations. A common sight in grocery markets or takeout stands is a man photographing a food display with his phone, cell-mailing the image to his spouse, and asking whether the food should be purchased. Meanwhile, bored children riding in the shopping cart play fortunetelling games on the family's second phone.

According to Mizuko Ito, an anthropologist at the University of Southern California's Annenberg Center for Communication, the reason for this rapid adoption of cellular technology lies less in the peculiarities of Japanese etiquette than in the nation's dense, urban population and relatively low rate of computer own-

TOM WAGNER/CORBIS SABA

"All that stuff in a woman's purse or a man's wallet should go into the phone," says Takeshi Natsuno.

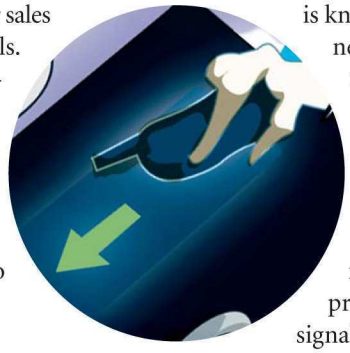
ership. "The Japanese spend tremendous amounts of time on mass transit and as pedestrians in cities," she says. "So where U.S. teenagers might sit in their suburban bedrooms and instant-message each other from their computers, Japanese kids, who don't have their own computers and their own bedrooms, are out on the train or in city streets texting each other on the keitai [cell phone]." As the U.S. grows denser, more urban, and more dependent on mass transit, it may well become more like Japan. "In that sense," Ito says, "Americans can look to Japan as the future."

DoCoMo has long fueled the Japanese love affair with cell phones. The firm officially began life in 1992, when the government eliminated NTT's previous monopoly on mobile communications. At that time cell phones were "an executive tool supplied by the corporation to a select few,"according to Kenji Kohiyama, a longtime NTT executive and director of DoCoMo House, a company-sponsored communications think tank at Keio University near Tokyo. In Kohiyama's view, cell phones did not become a mass-market item until 1994, when DoCoMo stopped leasing them to customers and began selling them outright at reduced cost, making up losses on their sales through the increased volume of telephone calls. Within two years, the number of DoCoMo subscribers doubled, from fewer than 1.5 million to almost three million. In five years, the number was almost 20 million.

That year—1999—the company introduced i-mode. "We thought the market for voice was saturated, so we had to do something," Natsuno says, half-joking. "So we brought the phone into the Internet—the virtual world."

Users at first could do little more than access a few score corporate websites. But because i-mode used a special, compact version of ordinary Web software rather than the wholly new software demanded by European and U.S. cell-phone companies, individuals and companies were quickly able to put up tens of thousands of i-mode sites, DoCoMo-endorsed or not. Meanwhile, DoCoMo kept expanding the capacities of the handsets; the newest models, introduced in March, can take two-megapixel photographs, read Word and Excel files, record up to two hours of audio, and run Flash animations and PlayStation-like games on screens that by U.S. standards are startlingly crisp and bright.

Today, says Natsuno, "We're starting to saturate on multimedia. So now we bring the phone to the real world."



A PHONE FOR ALL REASONS

With help from companies such as Coca-Cola, All Nippon Airways, and MasterCard, NTT DoCoMo is developing a bevy of practical uses for its i-mode FeliCa phones.

AT A VENDING MACHINE

Want a soft drink? Tap the phone against the special pad on the face of the vending machine. In the split second before the can drops down, the reader authenticates your phone, checks the amount in your account, and deducts the cost of a soda. The phone displays the purchase price and your remaining e-cash.

AT THE AIRPORT

Purchased an airline ticket online? After the transaction is complete, the airline e-mails an identifying code to your cell phone. At the airport, an automatic check-in machine verifies the code and uploads an electronic boarding pass to the phone. At the gate, another reader checks the boarding pass—confirming that, yes, you're going to Osaka—and you're allowed to board.

AT HOME

Want to unlock your front door? The phone's FeliCa chip stores an encrypted numerical key unique to your residence. Tap the phone on a card reader next to the door. The reader verifies the code and unlocks the door.

MAKING SMART CARDS WISE

At first, that mainly means equipping new phones with what is known as a "contactless IC" chip. Smaller and thinner than a dime, and attached to an antenna made from a thin film and embedded in the phone, the chip is like a small, fast, rather stupid computer, one that is exuberantly cheap to manufacture. The chip chosen by DoCoMo is Sony's FeliCa (the name comes from "felicity" and "card"), which has nine kilobytes of random-access memory and just enough smarts in its onboard programming to respond to the short-range radio signal beamed out by a chip reader/writer.

In Tokyo, the most familiar example of a reader is at the turnstile used in Japan Rail train and subway stations. From station vending machines, passengers buy "smart cards"—plastic rectangles the size and shape of a credit card with chips inside. Each card is "charged" with a predetermined sum: approximately $10, $30, or $50. People stick the cards inside their wallets and purses and slap them on the turnstile as they pass through. In the brief interval when the card brushes by the turnstile, the chip inside the card and the reader inside the turnstile perform a "cryptographic handshake"—that is, they exchange a set of encrypted messages. The turnstile tells the card its location; the card tells the turnstile how much money it contains; the turnstile deducts the base cost of a ticket. On the way out, the exit turnstile performs an analogous transaction, calculating the actual cost of the journey and deducting it from the card.

The entire transaction takes less than a tenth of a second. Not only does that help shuttle people quickly through the turnstiles, a key consideration for Japan Rail, but it also means the exchange of data takes place before users can pull away their cards. That reduces the risk of incomplete transactions—a major technical challenge in systems where cards do not physically pass through readers. According to Tadashi Morita, FeliCa's chief engineer at Sony (no relation to Sony's late founder, Akio Morita), slower systems run the risk that users will send payment information but walk past the readers before they have received their tickets in return. "They don't know if they've been charged or not," he says. "You don't want [people] to pay twice, or not at all."

Wireless payment systems are spreading fast. Hong Kong and Singapore have FeliCa systems in their subways so similar to those

Q+A WITH TAKESHI NATSUNO

"WE HAVE TO INNOVATE"

Takeshi Natsuno, NTT DoCoMo's director of i-mode strategy, is the main proponent of the company's effort to roll out all-in-one phones that take the place of cash, keys, credit cards, and other modern accoutrements. *Technology Review* contributing writer Charles C. Mann interviewed Natsuno at his Tokyo office.

TECHNOLOGY REVIEW: Introducing this new technology, which requires an expensive handset, just a few years after you asked consumers to adopt i-mode—which also required a costly new phone—is a gamble. Are you worried your customers won't want to adopt another format?

Takeshi Natsuno: Maybe, but we have to innovate. The history of the Japanese mobile-phone industry is that every five years it changes completely. Our company was founded in '92. For the first two years after it was set up, service was expensive and limited. We decided to sell handsets to the end user rather than leasing them. This changed the whole system. There was an explosion of demand....Our subscriptions increased from one or two million to 25 million. [In 1999] we realized the only new customers to get would be the lower-usage ones. We had to bring in something new to grow. So we added data use on top; we started i-mode. Now, already, more than 90 percent of the 45 million voice subscribers are i-mode users....But that market has matured.

TR: So how do you create new demand?

Natsuno: The next five years will link the phone to the real world. The first part is the contactless IC card. You'll use it on the post office register, as a building pass, a corporate ID, any kind of membership card, a credit card—the phone will replace the wallet in five years. Our goal is to have millions of people walking around without wallets in 2009.

TR: Isn't there a chicken-and-egg problem? People can't beam money from their phones until stores have payment mechanisms; but until a lot of people have the new phones, stores won't want to install new equipment.

Natsuno: This is a credit-card-like device. Credit card machines need to be replaced every three to five years. The new ones will be properly equipped. When I launched i-mode, it was our dream to have the Web inside a phone, so you could check your bank account and play games on your phone. Now that is all true, so I'm confident about the next five years. The phone will extend its reach.

TR: Into a kind of remote control for your life?

Natsuno: Literally! One application we are thinking about is for TV. If you have a DVR [digital video recorder], you can spend boring meetings in the office registering what TV program you want to record and call them in to your television. When you get home late, there they are. It's technologically easy to go beyond that, to send data to your air conditioner or appliances. All the technology is there. You just need a way to control it.

in Japan that the three governments are discussing the creation of pan-Asian transit cards. And in the United States, Washington, DC, subway riders can buy similar cards manufactured by Cubic Transportation Systems, of San Diego, which also set up the computing infrastructure behind the Chicago Transportation Authority's new contactless fare system.

But the cards do have disadvantages. Because users can't see how much money remains on their cards, they often discover that they have run out, or don't have enough to pay their fares, only when the doors slam shut on them as they try to walk through the turnstile. Exacerbating the humiliation, FeliCa cards are inconvenient to recharge: a card owner must back out of the turnstile through the rush-hour crowd, find the nearest FeliCa machine, and put the card and money into it. If a card is stolen, its owner may be out of luck: unlike credit cards, many FeliCa cards can't be canceled. Except, that is, when they cancel themselves; some Tokyo commuters report that the FeliCa chips go bad after a year or so in sweaty wallets, and that they have to whack them against the turnstile repeatedly to register transactions. When the cards die, their owners lose whatever money is still on them.

Connecting the smart card to a cell phone with a sophisticated display eliminates these problems at a stroke. Rather than having to feed bills into a special vending machine to recharge cards, users can check their balances by calling up bank websites and add funds to their accounts by direct deposit, then read their balances on the phone's screen. Protected by the carapace of the phone handset, the chips are less likely to go bad; even if they do break down, the bank records all transactions, preventing monetary losses. And if thieves snatch the phone, says Natsuno, "one call to DoCoMo cancels the thief's access to your phone—and your money."

More important to both Sony and DoCoMo, connecting the cell phone and the smart card opens up both to new uses, such as allowing phone owners to make small purchases at train- or subway-station vending machines and convenience stores. Later, as users gain experience with the system, DoCoMo will enable larger purchases. Items purchased with the FeliCa card could simply be added to monthly phone bills. (Having DoCoMo serve as a de facto collection agent should ease business fears about nonpayment, because the phone company wields the power to cut off phone access—a powerful disincentive in a country where phonelessness is tantamount to banishment.) According to company representative Nobuo Hori, the new phones are also being tested as corporate ID badges and apartment-door keys. "Post office registers, airport gates, building passes, any kind of membership card or loyalty card, business cards—all should be in your phone, so you don't have to carry around so many pieces of paper," Hori says.

Ultimately, says Sony's Morita, the phone should become the main interface between the networked devices in homes and offices and the people who own them. "You will walk into a room and tap your phone on the wall," he says, "and the room will know who you are." An office worker might go into an empty office to borrow a computer, for instance, and his phone would identify him to the computer, which would then let him access his own files. "Everything would be set up just by touching a couple of pads." Particularly interesting to Sony is the prospect of using the new phones for digital rights management. "The TV would know what programs you had paid for," Morita says. "The PlayStation would know what games you can play. You would touch the screen with the phone, and it would be ready with your content."

To Natsuno, such an environment is a practical, here-and-now version of ubiquitous computing. "You get so many engineers saying this is not true ubiquitous computing because it does not follow some technical rule they have invented." In his view, "the computers are everywhere, they are talking to each other, you are controlling them with the phone. This is ubiquitous as far as I am concerned.…We are just doing it without using the term." If it takes building a ubiquitous system to allow DoCoMo customers to "turn on their air conditioners when they are 15 minutes away from home on their commutes," he says, then "I'll build it."

The peril is that as the phones grow more powerful, they will become targets for thieves and con artists. "We don't want someone to walk around the platform with a stolen card-reader, downloading everyone's money," Morita says. "If people begin to think [the new phones] are insecure or violate their privacy, they will never use them."

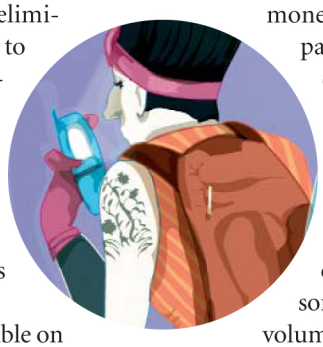
Critical to the security of the new system, he says, is the short transmission range of the FeliCa cards—only 10 centimeters, which makes it difficult for thieves to scan them. But according to Bruce Schneier, chief technical officer of Counterpane Internet Security in Mountain View, CA, this isn't much of a defense.

"THE COMPUTERS ARE EVERYWHERE, THEY ARE TALKING TO EACH OTHER, YOU ARE CONTROLLING THEM WITH THE PHONE. THIS IS UBIQUITOUS AS FAR AS I AM CONCERNED."

DOING IT RIGHT

In fact, he's building it already. Parts of DoCoMo's vision, such as the payment and identification schemes, are already being tested; more will be rolled out as the FeliCa phones, which will probably cost $200 to $300, are introduced this summer. To Morita, the barriers to full deployment are more societal than technological. "We could do most of these things today," he says. "And we would be doing them today, if we weren't worried about the security implications. And the privacy issues, too."

Because Japan has more experience with mobile communications than the United States, it has virtually eliminated some cell-phone annoyances that continue to plague Americans. With the advent of text-messaging, says Ito, the anthropologist, "people just don't talk on their phones on the subway anymore." To avoid the nuisance of pealing phones in public spaces, she says, more and more Japanese "turn off the ringers when they leave their homes in the morning, and the ringers stay off all day long."



The results of this socialization process are visible on any train platform in Japan. At any given time, a large minority of the waiting commuters—perhaps even half—will be using their phones. But almost nobody will actually be speaking on them. Instead, they will be sending or reading messages, checking weather or traffic websites, playing games, or (apparently a particular favorite among women) eliciting predictions about future romance from online fortunetelling programs.

To DoCoMo, the people staring into their phones are both an opportunity and a worry. The opportunity is to find more ways for them to use their phones, up- and downloading more packets of data. (DoCoMo charges roughly two-tenths of a cent for every 128 bits that go in or out of its phones; users may pay a penny per text message or a few cents to download a Web page.) One big new opportunity is shopping. Online users will be able to find items on i-mode websites and immediately buy them with digital cash stored directly in their handsets. Offline, in the real world, DoCoMo is focusing first on train stations, which are full of restaurants, department stores, and kiosks that sell the small, beautifully wrapped gifts of food that lubricate social occasions in Japan. In both cases, DoCoMo expects to generate more revenue as it sells more bits.

"People will steal and hack the card readers to make them more powerful," he says. "You could probably get the read distance up to a couple of meters, and then you would be able to rob a roomful of people just by walking around them."

Nonetheless, Schneier is cautiously enthusiastic about the phone–smart card combination. In 1999, he cowrote a now classic analysis of smart cards' security weaknesses. "Most of the bad things happen because there is no good way of telling who the card belongs to—who is supposed to be responsible for it," he says. But DoCoMo controls the FeliCa phones. "If somebody steals your money, they have to collect it through the phone company," he says. "They have to explain what they are doing trying to get your money, and that's hard."

The flip side of DoCoMo's control is that the company also controls the records of users' behavior—not only what phone calls they make, but what e-mails they send, where they go (subway fares), what they buy (FeliCa purchases), and a host of other things. If the phones are successful, the personal information compiled by DoCoMo will grow to volumes guaranteed to alarm civil libertarians.

But Schneier downplays the privacy concerns, arguing that people have already given up control of their personal data to innumerable banks, credit agencies, and retail establishments. "Something like this is going to happen, and everyone knows it," he says. "These Japanese companies have tremendously competent people. There's a good chance they might do it right."

Back at DoCoMo, Natsuno is confident that the company will not only do ubiquitous computing right but do it first, and do it profitably. U.S. companies are "years behind," he says—but not because Japan's technology is more advanced. Pointing to the automatic toll-collection devices in many U.S. cars, he says, "You could have put those in cell phones and built on that to introduce Web services, or almost any of the other things we have done." The real reason for DoCoMo's lead, Natsuno believes, "is that we have a business model. We will give the consumer ubiquitous computing and digital money and all of those other things the engineers want. But we will do it by giving people a way to get through the turnstile faster or to arrive at a house that is cooled to the right temperature and has a movie ready to play on the TV." TR

TR contributing writer **Charles C. Mann** is spending the year in Tokyo.

THE WORLD'S TALLEST BUILDING [FOR NOW]

A NEW FINANCIAL CENTER IN TAIPEI, TAIWAN, NOW CROWNS THE GLOBE'S SKYLINE. BUT NOT FOR LONG: EVEN TALLER STRUCTURES ARE POISED FOR CONSTRUCTION IN NEW YORK CITY AND DUBAI. By Patric Hadenius

SEIZING THE TITLE of "world's tallest building"—be it Joseph Pulitzer's 20-story *New York World* newspaper building in lower Manhattan in 1890, the Empire State Building in 1931, or Kuala Lumpur, Malaysia's gargantuan Petronas Towers in 1998—has always been about pushing the limits of architecture and engineering. But three years after the attacks of September 11 demonstrated how vulnerable such buildings are to terrorists, a surprising new competition is under way. The latest skyline king is a vaguely pagoda-like tower in Taipei, Taiwan, called Taipei 101 *(see "Inside Taipei 101," p. 52)*. Slated for occupancy this fall, the 101-story structure stands 508 meters tall, more than half a football field higher

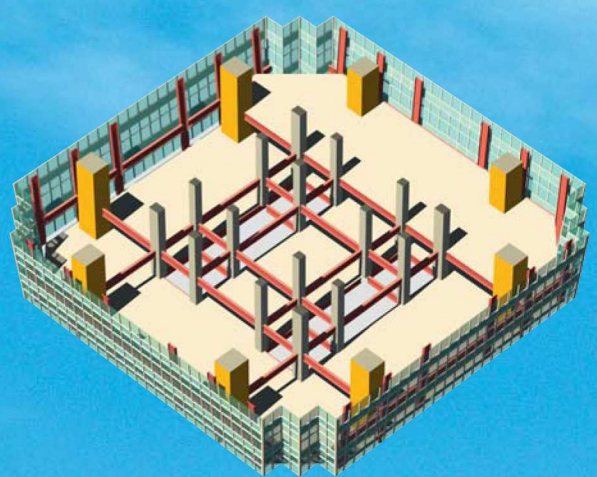
(Continued on page 54)

COURTESY OF TAIPEI FINANCIAL CENTER CORP.

INSIDE TAIPEI 101

Taiwan's record-breaking 508-meter, 101-story skyscraper is built to withstand frequent typhoons and occasional earthquakes. It sports the world's fastest elevators and largest antisway system, seismic sensors, and Internet-linked security systems. **ILLUSTRATIONS BY JOHN MACNEILL**

EMERGENCY REFUGE AREAS every eight floors provide places to escape smoke and fire. The refuge areas are accessible via pressurized stairways. Firefighters can reach them by means of dedicated, specially reinforced elevators that avoid conflict with escapees.



EIGHT CONCRETE-AND-STEEL SUPERCOLUMNS, measuring 2.4 by three meters at the bottom, carry the full load of the building and are designed to handle earthquake and typhoon forces. Smaller steel beams surround central stairways and elevators.

SENSOR AND SECURITY INFRASTRUCTURE

Seismic: Thirty seismic activity sensors monitor vertical and horizontal motions on six levels of the building.

Security: A total of 520 surveillance cameras, 330 radio frequency identification card readers, 170 security intercoms, and 2,600 door monitors protect occupants and can be controlled or monitored via the Internet.

Communications: Some 22.5 kilometers of fiber-optic cable carry data at one gigabyte per second and are backed up by microwave and satellite communication systems.

THE TOWER CONTAINS

- 198,347 square meters of office space
- 77,033 square meters of retail space
- 83,000 square meters of parking, enough for at least 1,800 vehicles

A 680,000-KILOGRAM STEEL BALL, suspended from cables at the 92nd floor and visible from observation decks and a restaurant, stabilizes the building. When the building is pushed one way by wind, the massive ball swings in the other direction, absorbing energy and limiting building motion. It's the largest antisway system of its kind in the world.

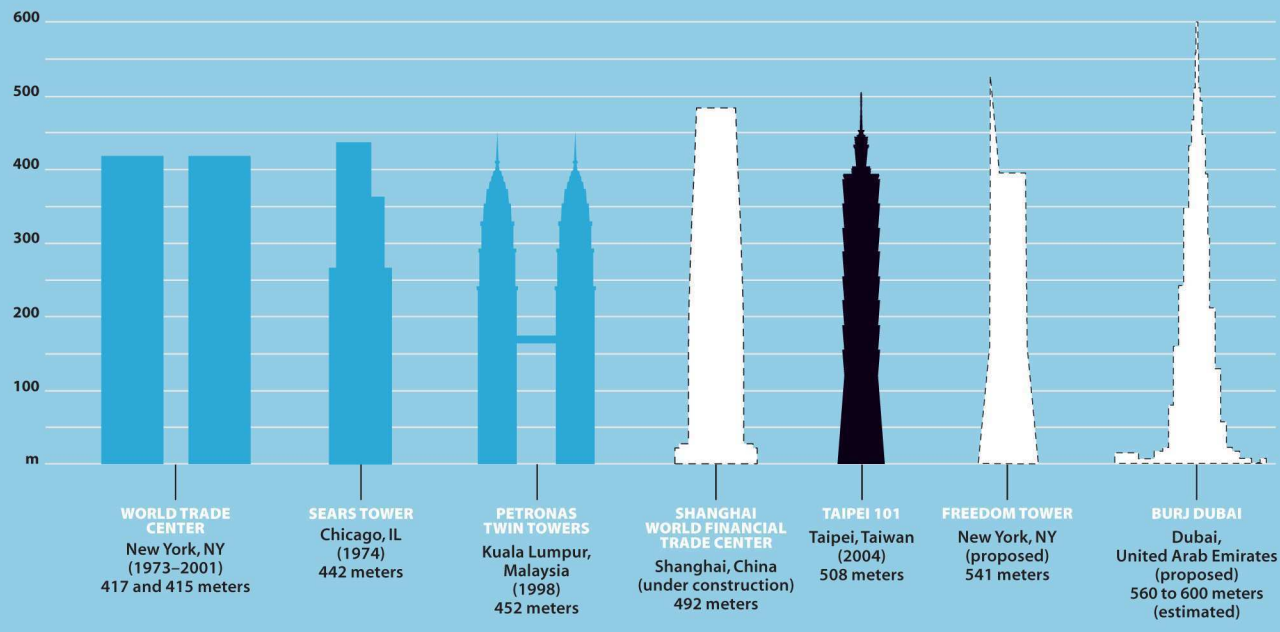
CORNER CUTOUTS on the building's facade were shown by software to diffuse the impact of wind. During typhoon season, Taiwan is often buffeted by winds topping 160 kilometers per hour.

THE FASTEST ELEVATORS in the world carry passengers from the first to the 89th floor at speeds as great as 1,010 meters per minute (38 miles per hour). An elevator cab (right, shown below floor level) is bullet shaped to make less sound, pressurized to be soft on passenger eardrums, and almost vibration free thanks to a damping system that senses shaking and counteracts it with small weights.

OUTWARD-SLOPING windows have a seven-degree pitch above the first 25 floors, avoiding direct sunlight, allowing for energy conservation, and providing for better city views.

CROWDED AT THE TOP

SOARING 101 STORIES AND 508 METERS to the tip of its spire, Taipei 101 is currently the tallest building in the world, in terms of highest structural element (a designation that excludes antennae). It eclipses the Petronas Twin Towers, which in 1998 claimed the title from Chicago's Sears Tower, ending its 24-year reign. Even taller buildings are proposed for New York City's ground zero and Dubai, United Arab Emirates. A tower nearly as tall as Taipei 101 is under construction in Shanghai, China.



(Continued from page 51)

than Petronas. On the horizon are even taller skyscrapers, including the Freedom Tower proposed for New York City's ground zero, and a business and residential colossus in Dubai, United Arab Emirates.

It's getting crowded at the top: several other massive skyscrapers, while not quite record-setters, have risen in Asian cities in the past decade, with another under construction in Shanghai, China. Indeed, eight of the world's ten tallest buildings are now in Asia. "Some Asian economies have grown more wealthy than before, and they now want to express their identities," says C. P. Wang, the architect of Taipei 101. "To me, a skyscraper is an easy way to do that." Indeed, proclaims Gail Fenske, an architecture professor at Roger Williams University in Bristol, RI, the world is in the midst of "a new skyscraper frenzy."

The world is in the midst of a new skyscraper frenzy. Armed with the latest design software, engineers are pushing the limits as far as they can.

The height records themselves can't be credited to any breakthrough in technology. Apart from the introduction of higher-grade steel, composite materials, and new welding techniques, basic construction methods haven't changed much in the past couple of decades.

Still, technology is a key enabler of this "frenzy." For starters, the latest software helps architects and engineers work together, and with numerous models at the same time, says Dennis Poon, managing principal for Taipei 101 at Thornton-Tomasetti Engineers in New York City. "With these new tools, we can do quick 3-D analyses of several different types of designs," says Poon. "We just don't have to guess." It is these analyses that make it possible to quickly determine the best designs for building the world's tallest building in a typhoon- and earthquake-prone area like Taipei.

And basic structural improvements fortify these buildings. Unlike the World Trade Center, the new skyscrapers have hardened-concrete cores that house elevators and stairways, better protecting potential escapees from fire and blast damage. Sensing and communications technologies—among them structural sensors that monitor swaying and radio frequency identification systems to enhance security—improve the buildings' operation. The latest elevators include smart controls that do things like dampen vibrations and regulate air pressure. In all these areas, says Fenske, "the engineers are pushing the limits as far as they can."

The result will be a new set of skyscraper records—ones that other engineers will surely seek to surpass in the years and decades to come. TR

Patric Hadenius is a senior editor at *Forskning och Framsteg*, a Swedish science and technology magazine, where he frequently writes about technology and language.

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Computing Gets Physical

A new generation of gesture recognition interfaces—for everything from playing games to showing the TV weather—could change how we interact with machines.

BY DAVID KUSHNER PHOTOGRAPHS BY TIMOTHY ARCHIBALD

Game on: Sony's Richard Marks demonstrates the EyeToy, which lets you put your whole body into a video game.

FOR ONCE, I control the weather.

I'm standing in front of a green backdrop inside a windowless studio at Cybernet Systems, a technology research and development company in Ann Arbor, MI. A digital camera in front of me is beaming my image, real time, to a television monitor that shows a scene typical of a nightly news weather report. There I am, standing before a map of the Midwest. I extend my arm and begin twirling my hand over the blip of Detroit. The map behind me zooms in on the area beneath my palm. The city widens into view and comes into focus. Looks like it's going to be a wet one, folks.

This is GestureStorm—a software system Cybernet developed to let weather broadcasters run through their forecasts with simple flicks of the hand. No wires. No buttons. No geeky audiovisual control panels. Move a hand one way, and you paint raindrops on-screen. Move it another, and you stir up a tornado. The interface is completely a matter of gesture. And if a lot of people have their way, this is only the beginning. Gesture recognition technology aims to become this millennium's remote control—a fluid, freeing means of interacting with all the digital stuff around us. Think *Minority Report.* In that film, Tom Cruise stands before a futuristic digital display, pointing and waving his way through a cascade of images and documents. This stuff, once the domain of science fiction, is finally creeping into the real world.

In Orlando, FL, WKMG became the first television station to use GestureStorm when it unveiled the system in December. In July 2003, Sony Computer Entertainment released the EyeToy, a PlayStation 2 peripheral that, using special software and an inexpensive digital camera, can project a video feed of a player into a game, even responding to the player's movements; instead of zapping a bad guy with a controller button, the gamer gives him a swift karate chop. This year, two companies will debut virtual keyboards that let people control personal digital assistants and even automotive equipment with gestures. As far as Charles Cohen, vice president for research and development at Cybernet, is concerned, gesture recognition's time has come. "Gesture recognition is remote control with a wave of a hand," he says.

As I unleash some storm clouds over Detroit, I see what he means. Of course, playing weatherman is one thing, but importing gesture recognition into daily life is another, as Cohen and the others pioneering the technology are learning. "I don't know what the killer app for gesture recognition is yet," Cohen confesses.

GET IN THE GAME

On the frontier of gesture recognition technology, there may be no better judge of a killer app than a four-year-old. That's who I enlisted when I first hooked my PlayStation 2 up to an EyeToy—an unassuming device that's shaping up to be the Pong of gesture interfaces. Intuitive, fun, and physical, it embodies the promise of gesture recognition wares. That promise is freedom—freedom from 14-button controllers, keyboards, mice, cables. "Everyone agrees that the keyboard isn't necessarily the most optimal way to interface," says senior analyst Joe Laszlo of Jupiter Research, a technology research firm based in New York City.

The EyeToy might be the first gesture recognition device to deliver a viable alternative to a keyboard or game controller. The hardware is a black-ribbed, rectangular digital camera about the size of a deck of cards. It plugs into the USB port on the front of the PlayStation. For about $50, you get the camera plus a CD of 12 games. Once the device is connected, you put it on top of your television set and angle it forward. The outline of a human body appears in the center of the screen, and you position yourself before the camera so that you fill it in.

"Four-year-old, come hither!" I say, helping my daughter to stand in the middle of the outlined shape. She waves at herself cautiously. "Where's the game?" she asks. "You're in it!" I respond. In front of her image on-screen floats a swarm of multicolored discs. To make a selection, she must wave her hand over the disc representing the game she'd like to play. The games are simple, almost like 21st-century versions of the old Atari classics Tennis and Combat. There's a boxing game, a juggling game, a dancing game.

My daughter likes the sound of Wishi Washi, so Wishi Washi it is. Foamy bubbles cover the screen in front of her image. The object of the game is to "wipe" the screen clean to the strains of Dixieland jazz. Hesitantly at first, she waves her arm as if she were making a snow angel, and a corresponding blob of bubbles on-screen vanishes. The camera is capturing her movements, real time; before long she realizes she can use more than just her hands. By the end, she is jumping, leaning, kicking, flapping, using every physical motion she can muster to wipe away the foam. It's not often you see a gamer sweat.

And plenty of gamers are sweating over the EyeToy. In the gaming business, sales of 500,000 constitute a hit. As of March, more than 500,000 EyeToys had been sold in the United States and more than two million in Europe.

Video from the tiny EyeToy camera is compressed and fed through the USB port. Once inside the PlayStation, the video is processed through "conceptual subtraction," which compares the

Gesture recognition promises freedom—freedom from 14-button controllers, keyboards, mice, cables.

images in successive frames. The entire transaction uses less than 10 percent of the PlayStation 2's processing power, leaving a hefty 90 percent to render the explosions, foam baths, and other graphics features of the games themselves.

In its current iteration, the EyeToy is limited to motion detection, but later versions will include more advanced features. Sony has already developed EyeToy software that can, for example, track different colors in an environment—even different faces. And it can deliver the sort of gesture recognition capabilities that would make, say, a Harry Potter video game truly come to life: draw a triangle with your wand and unleash a firestorm on-screen; draw a circle and turn your enemy into snow. "You'll be able to cast a different kind of magic spell according to the shapes you draw in the air," says Richard Marks, special-projects manager for research and development at Sony Computer Entertainment of America. EyeToy is his brainchild. Marks began working in the field of "computer vision"—technology that enables computers to perceive their surroundings—while developing cameras for underwater robots at the Monterey Bay

Wishi Washi workout: After hooking up the EyeToy camera to a PlayStation console, you move your body around to make things happen on the screen.

Gesture guys: Cybernet founder Charles Cohen (left) and research engineer Gene Foulk

SCOTT SAWYER

Aquarium Research Institute in Moss Landing, CA. "I thought the PlayStation 2 would be good at computer vision," he says.

But there are shortcomings. The USB port's limited data-handling capacity results in fuzzy video and makes multiplayer online EyeToy experiences impossible. And the software can have difficulty discerning a player's movements in a bright and busy environment—such as a typical family room. Marks says these problems will fade when the PlayStation 3 hits shelves, probably some time in 2006. The next-generation console will include a USB 2.0 port—as much as 40 times faster than a USB 1—which will reduce the fuzziness. Recognizing gestures against bright and busy backgrounds might require gamers to wave hot-pink wands or slip on gloves. Sony is distributing software tools that will help game developers exploit the new technology.

The ultimate goal is that you won't need any prop at all. "The only thing you'll need," Marks says, "is your hand."

"HOW COME WE NEVER THOUGHT OF THIS?"

Cybernet has emerged as ground zero for the commercialization of gesture interface technology. I've stared at a computer screen for countless hours, but on this morning inside the company's offices, things somehow look different. On the screen is a typical assortment of folders and program icons. When I look at the Internet Explorer icon in the upper left-hand corner, however, something strange happens. The cursor moves toward where I'm looking. No mouse. No keyboards. My hands are resting at my sides. It's like a Ouija board.

I'm using Navigaze, a new interface based entirely on eye movement. Instead of double-clicking, for example, you double-blink; with Navigaze, Christopher Reeve could surf the Web. Cybernet will roll out Navigaze this spring, along with an improved version of a gaming technology called Use Your Head—a system (first introduced in 2000) that lets you input directional instructions by bobbing your noggin. A camera tracks a player's head motion, and the on-screen image changes accordingly: lean left, and your field of vision turns left; lean right, and the view shifts the other way.

Cybernet made its name in the late 1980s in force feedback, the haptic technology now available for video games as well as in the automotive and medical industries. Cohen sees gesture recognition as another field ready to bloom. "Gesture recognition is in the stage that force feedback was in ten years ago," he says.

One of Cybernet's earliest forays into gesture recognition came in 1998, when the U.S. Army contracted with the company to create a gesture-based computerized training system: a

trainee could command a troop of simulated soldiers by making a variety of hand movements. NASA commissioned the company to create a gesture-based information kiosk for the public, but that project didn't get far. "Students kept putting their gum on the kiosk and messing it up," Cohen says.

So far, the closest the company has come to finding the killer app for gesture interface is a military system that enables the manipulation of images on command-and-control maps. After reading a press release about the work, a television station expressed interest in adapting the technology for its meteorologist. "It was perfect!" Cohen recalls. "How come we never thought of this?"

Gesture-based interfaces would not necessarily supplant the familiar keyboard and mouse, but rather supplement them.

The TV weather application was perfect for one primary reason: its surrounding environment didn't have to be engineered. EyeToy, by contrast, works only if you stand in a certain place relative to the camera; if someone blocks the camera's view, everything goes haywire. Because a TV meteorologist stands in front of a consistent, unobstructed background, there would be no such disruptions to contend with.

VIRTUAL KEYBOARDS AND BEYOND

The clouds have parted. The rain has ceased. As I finish my round of GestureStorm theatrics, I decide to shoo away the clouds and let Detroit return to its peace and calm once again.

Over lunch at a nearby Italian restaurant, Cybernet's Cohen suggests that the mission of gesture recognition is not necessarily to supplant the old keyboard and mouse but, rather, to supplement them. "I won't say gesture recognition is the be-all and end-all," he says.

Indeed, one intriguing application illustrates the way that gesture technology could dovetail with conventional interfaces. A device from San Jose, CA-based Canesta—due out later this year—brings gesture recognition to personal digital assistants. The device projects an image of a keyboard onto a flat surface, such as a desk, through a tiny lens inside the PDA. An infrared light beam directed at the zone just above the projected keyboard senses precisely where the user's fingers are at any instant: the device monitors the time it takes for a pulse of infrared light to leave the emitter, bounce off the moving fingertips, and return to a sensor in the PDA. A pulse's round-trip travel time corresponds with a specific distance, providing a 3-D map of the fingertips' position over the keys, so whatever the user types on the virtual keyboard is captured digitally inside the PDA.

The Canesta device operates at more than 50 frames per second, so it can keep up with even the speediest typist. Because Canesta's technology uses infrared light to measure the distance to the object, it could potentially alleviate one of the problems facing Sony and Cybernet: how to perceive gestures against a bright or busy background. With the current configuration of the EyeToy, for example, I'd seriously mess up my daughter's game of Wishi Washi if I passed in front of the camera's background while she's playing. If Canesta's infrared light were trained on her, and her alone, the game wouldn't register my interruption. Canesta considers the $11 billion video game industry to be a future target area and says it has talked with a number of major players in the electronic-entertainment business. Later this year, a Jerusalem, Israel, company called VKB will introduce a competing virtual keyboard that employs technology similar to Canesta's.

Beyond keyboards, weather forecasting, and games, gesture recognition technology could transform the way people interact with computers in a variety of settings. Universities have been working on the technology for years. Researchers at the Georgia Institute of Technology, for example, have explored how gesture recognition may help reduce automobile accidents. A group led by Thad Starner has created what it calls a "gesture panel" in place of a standard dashboard control. The driver adjusts the car's temperature or sound system volume by maneuvering her hand over a designated area, without having to take her eyes off the road.

Researchers at MIT's Media Laboratory have studied ways in which gestures could be used to enhance various entertainment devices. A "StoryMat," for example, could recognize and react to movements of particular toys on a child's play mat. A "conversational humanoid" senses and responds to a person's motions, as reported by a wearable, electromagnetic tracking device. Other projects examine the emotional messages that gestures and posture convey. Research has shown that it's possible to program machines to discern the interest—or lack thereof—that children display when interacting with educational software, says Rosalind W. Picard, director of the lab's affective-computing research group. A program that incorporated such inadvertent user input could respond accordingly—perhaps by switching activities when the user slumped in apparent boredom.

Not surprisingly, some effort has also gone toward endowing Microsoft products with gesture interfaces. During the 1990s, researchers at the University of Cambridge in England developed an experimental system called Jester that employed gesture recognition for surfing through Windows; it never made it out of the lab. Another truly killer application would be a gesture interface for PowerPoint—the ubiquitous presentation software. At Cybernet, Cohen is working on such an interface himself. It could require the presenter to slip on a glove that would be recognized by the computer's eye. One can only imagine the fashion possibilities.

For now, however, there's nothing quite as efficient and responsive as the keyboard I'm typing on at the moment. It works in any shade of light. It doesn't get confused if my kid darts into the room. And with the help of a mouse, it lets me call up my files quicker than I can blink.

"Whenever you want to introduce a new user interface," analyst Laszlo says, "simplicity and intuitiveness are key. When the mouse was introduced, the learning curve wasn't steep."

And that gives companies like Cybernet some hope. Because there's nothing more intuitive than a wave of the hand.

David Kushner is a contributing writer for *Technology Review* who covers digital entertainment technology. He is the author of *Masters of Doom: How Two Guys Created an Empire and Transformed Pop Culture*.

SPOTTING CANCER SOONER

By Ken Garber

ILLUSTRATION BY LISA FRANKE
PHOTOGRAPHS BY DAVID DEAL

Simple but accurate blood tests may soon make it possible to detect cancer while it can still be cured.


No. 46
No.
lung
breast
stomach
ovary

THE INDIVIDUAL FATES of the 1.3 million Americans diagnosed with cancer this year will be largely decided by one simple factor: at what stage was the disease spotted?

Ovarian cancer offers a fearsome example. Because of its vague symptoms, it is usually ignored or misdiagnosed, sometimes for years. Eighty percent of patients don't find out they have it until it's spread beyond the ovaries. At that point, it is usually incurable; only one patient in three survives five years after diagnosis. On the other hand, surgery can cure 90 percent of patients whose cancer is detected while still confined to the ovary. Even notoriously lethal cancers of the lung and pancreas are anything but a death sentence, if caught early enough. "Cancers can almost always be cured by simple, classical surgical techniques, if they're detected early," says Bert Vogelstein, a molecular geneticist at the Howard Hughes Medical Institute at Johns Hopkins.

The problem, of course, is that cancers, which begin with just a few deviant cells, are by their very nature hard to diagnose early. In the last few years, though, a new method has emerged that promises to deliver simple blood tests that identify the telltale molecular profiles of various cancers easily and accurately. It has long been known that cancer leaves traces in the blood, but these hints are confusing and ambiguous. "Blood is perfusing through every tissue in your body, 60 times a second, beating through it," says National Institutes of Health pathologist Lance Liotta. "You'd imagine there'd be fragments of what's going on in every cell, and every tissue, ending up in the circulation."

Indeed, medical researchers have struggled for years to create blood tests that would detect particular proteins produced by cancer cells. But the few such protein "markers" discovered to date haven't proved very useful for early detection, since none of them is produced solely by cancer cells. The new method, by contrast, mines the blood for patterns of proteins; these patterns should, in theory, identify a cancer with the clarity and uniqueness of a human fingerprint. And such patterns can be detected long before symptoms of disease appear.

Corporate, academic, and government researchers are all racing to develop reliable screening tests based on these protein patterns *(see "Protein Profiling to Detect Cancer," p. 66)*. The first such test, for ovarian cancer, is already being evaluated in patients. It could be available within a few years, to be followed by tests for prostate, lung, breast, renal, and pancreatic cancer, as well as leukemia and lymphoma. In the long term, a single drop of blood may be all that's needed to screen for every major cancer.

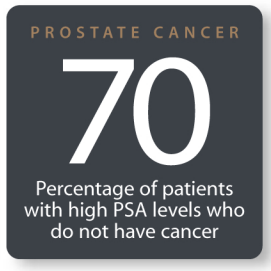
PROTEIN PROFILING

Routine screening for most types of cancer does not exist today. With a few important exceptions, cancer screening has been a failure; even widely endorsed methods, such as breast and testicular self-exams and mammography, have come under fire. These tests miss too many cancers and pick up too many "false positives," suspicious findings that turn out to be benign. The result: much anxiety, many unnecessary biopsies and exploratory operations—and relatively few cures.

The few existing blood tests for cancer aren't any better. Take, for example, PSA, the test for prostate cancer, and CA-125, for ovarian cancer. Both are named after the proteins they look for, and both are terrible. PSA, which the American Urological Society recommends offering to every man over age 50, "misses about a third of patients with cancer," says David Sidransky, a cancer researcher at Johns Hopkins, "and it falsely calls patients that are positive with PSA as having cancer about a third of the time." For ovarian cancer, the picture looks even worse. Only about half of patients with early-stage ovarian cancer show elevated CA-125 levels, and the rate of false positives is high, because some benign conditions cause overproduction of the protein. As a result, CA-125 is only approved for monitoring the progression or recurrence of ovarian cancer, not for screening.

George Wright, a cell biologist at the Eastern Virginia Medical School in Norfolk, has spent his entire research career of more than 40 years trying to find better diagnostic markers for early cancer detection. He has been understandably frustrated. "Maybe a protein biomarker that [we] discovered would detect 20 to 30 percent, not 100 percent, of the cancers," says Wright. Equally useless are markers that falsely diagnose healthy people as ill, regardless of how many cancers they reveal. To be useful for routine screening, a blood test for cancer has to be almost perfect.

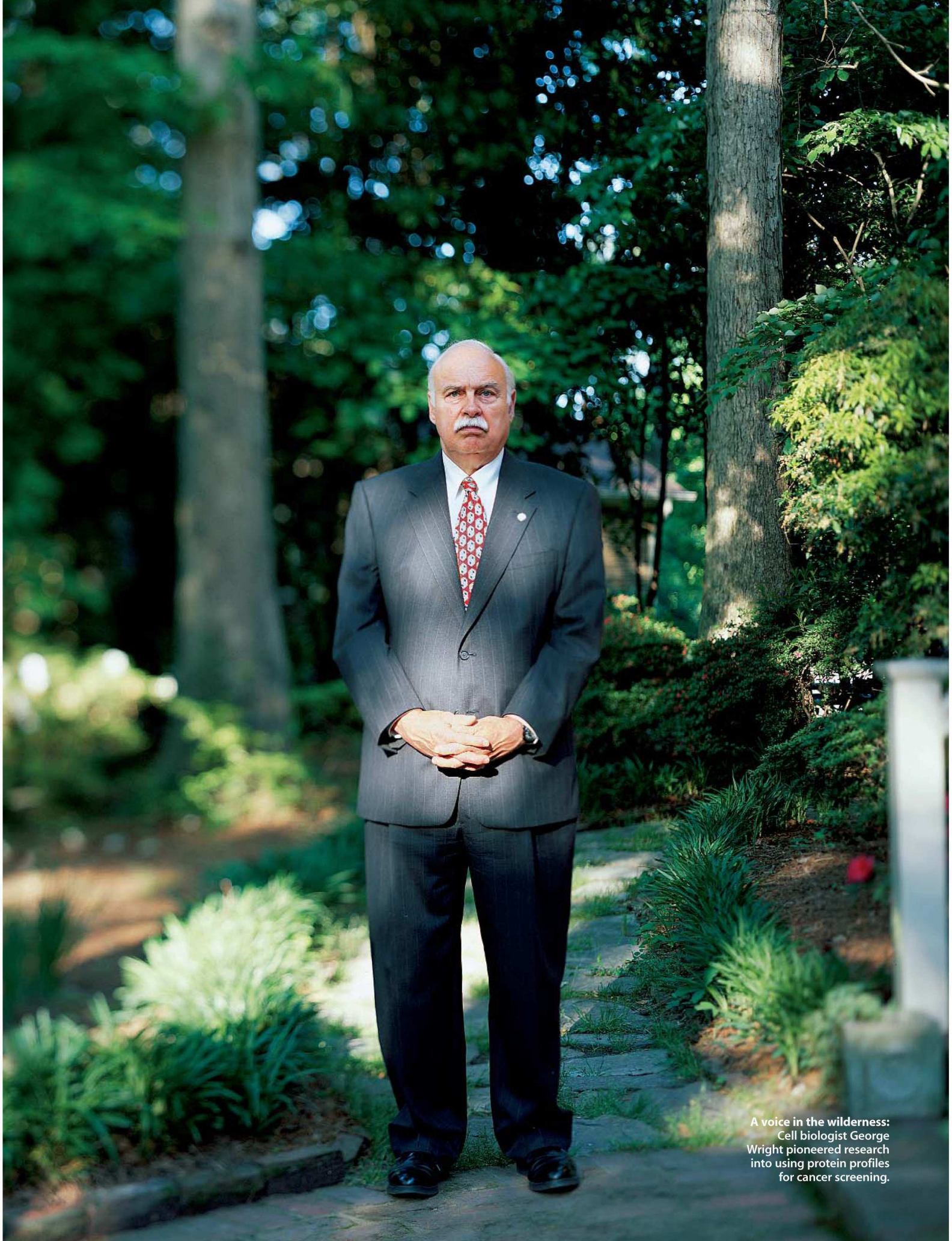
In 1998, Wright read an article in a trade magazine about a biotech company in California that was looking at protein patterns; suddenly, that almost-perfect test seemed possible. The Fremont-based company, Ciphergen Biosystems, claimed that a few drops of blood could reveal hundreds of proteins simultaneously, when analyzed with a standard laboratory instrument called a mass spectrometer. The proteins, though, aren't explicitly identified; instead, the machine prints out a pattern of sharp peaks and troughs, each peak representing the blood level of some unknown protein. Ciphergen thought that comparing the results from cancer patients to those from healthy subjects could aid the search for cancer biomarkers, because many proteins are overproduced in tumor cells. Properly identified and studied, those proteins could lead to better cancer tests. But Wright had an even bolder idea: the patterns themselves might provide a ready-made signature for cancer. The strategy of using patterns, if it worked, would shave years, even decades, off the time required to create a test, since it would eliminate the need to identify the individual proteins and perfect means to detect them.



Wright also suspected that tests based on cancer protein profiles could fingerprint cancer more accurately than any one protein. They "would be more effective than anything that was available," he recalls telling Ciphergen's CEO, who was skeptical. But Wright bought a Ciphergen machine in January 1999 and began looking for incriminating patterns himself.

SKETCHING A SOLUTION

Wright was not alone. Around the time he was beginning his work, the same approach occurred to NIH's Liotta and U.S. Food and Drug Administration researcher Emanuel Petricoin.



A voice in the wilderness: Cell biologist George Wright pioneered research into using protein profiles for cancer screening.

Petricoin and Liotta knew that cancer, on the level of the cell, generates a cacophony of changes, both in the tumor tissue and in the normal tissue surrounding it. This complexity appears impenetrable. But the duo thought they could exploit that very complexity to generate a cancer fingerprint from traces of the disease circulating in the blood.

Like Wright, Petricoin and Liotta used a Ciphergen system to generate protein profiles from blood samples. Their early attempts to find cancer patterns failed, though, because they were simply trying to juggle too much information. Then, in June 1999, a solution appeared. Petricoin and his friend Peter Levine, a Maryland lawyer with a background in data analysis, were chatting about the problem over brunch; Levine suggested using pattern recognition algorithms to make sense of the massive amount of data. Levine, who had considered using such algorithms to analyze stock market trends and commodities trading, sketched out the cancer idea on a napkin. "In about five minutes, we both realized this would be a really fascinating approach," Petricoin recalls.

LUNG CANCER

0

Number of proven screening tests for this most deadly of cancers

So they tested it, together with Ben Hitt, a software engineer who borrowed the necessary algorithms from artificial-intelligence theory. In fact, cancer patterns did emerge, and in 2000 Levine and Hitt founded Correlogic Systems to develop blood tests for cancers. In early 2002, the researchers published results in the British medical journal *Lancet*, showing they could use a specific protein pattern to spot ovarian cancer. Their test correctly identified 50 out of 50 women with cancer and correctly scored negative for 63 out of 66 unaffected women. Later given the name OvaCheck, it promised to be the first blood test accurate enough to be used for general ovarian-cancer screening. By the end of 2002, Correlogic had licensed OvaCheck to two major commercial laboratories and planned a 2004 product launch.

Meanwhile, Wright's group in Virginia was also pushing ahead. Using a different algorithm, Wright and Eastern Virginia molecular biologist John Semmes showed that a protein pattern could distinguish prostate cancer from a common noncancerous condition, benign prostatic hypertrophy, in 25 out of 30 cases. The PSA test, by contrast, is unable to distinguish the two conditions.

While Wright stresses that the results are preliminary, the technology continues to inch toward commercialization. A large initial trial across many medical centers should finish in about a year; a final validation trial will conclude, if all goes well, in 2006. And Eastern Virginia has already licensed its technology to an undisclosed company for eventual development into a full-blown diagnostic test.

JUNK SCIENCE?

Given the stakes, a cautious approach makes sense. In fact, Correlogic, which has advanced its technology much more aggressively than the Eastern Virginia group, suffered a critical setback last winter. In September 2003, Correlogic announced at the annual meeting of the Ovarian Cancer National Alliance, a patient advocacy group, that OvaCheck would be on the market early in 2004. But in February, marketing plans went on hold when the FDA notified Correlogic and its two partners that the test might need regulatory approval—something not usually required of diagnostic tests marketed by clinical laboratories. Now the company and the FDA are working out a plan for moving forward.

"The biggest mistake…was to announce that you have a blood test," says Eastern Virginia's Semmes, who notes that Correlogic hadn't even finalized its diagnostic pattern, at least in published form, at the time it made the announcement. "That claim, I think, hurt the field tremendously." Even Petricoin and Liotta have distanced themselves from the test they helped originate.

PROTEIN PROFILING TO DETECT CANCER*

ADVANCED BIO/CHEM
LOCATION: The Woodlands, TX
CANCER TARGET: Breast
STATUS: Preparing clinical trial for disease recurrence test that uses breast ductal fluid; possible launch in 2005

CIPHERGEN BIOSYSTEMS
LOCATION: Fremont, CA
CANCER TARGET: Ovarian, prostate, pancreatic, breast
STATUS: Ovarian-cancer test scheduled for commercial launch by early 2005

CORRELOGIC SYSTEMS
LOCATION: Bethesda, MD
CANCER TARGET: Ovarian, prostate
STATUS: Ovarian test undergoing multicenter human trials; early-2004 launch postponed

ROSAMONDE BANKS
LOCATION: University of Leeds, England
CANCER TARGET: Kidney
STATUS: Preliminary studies

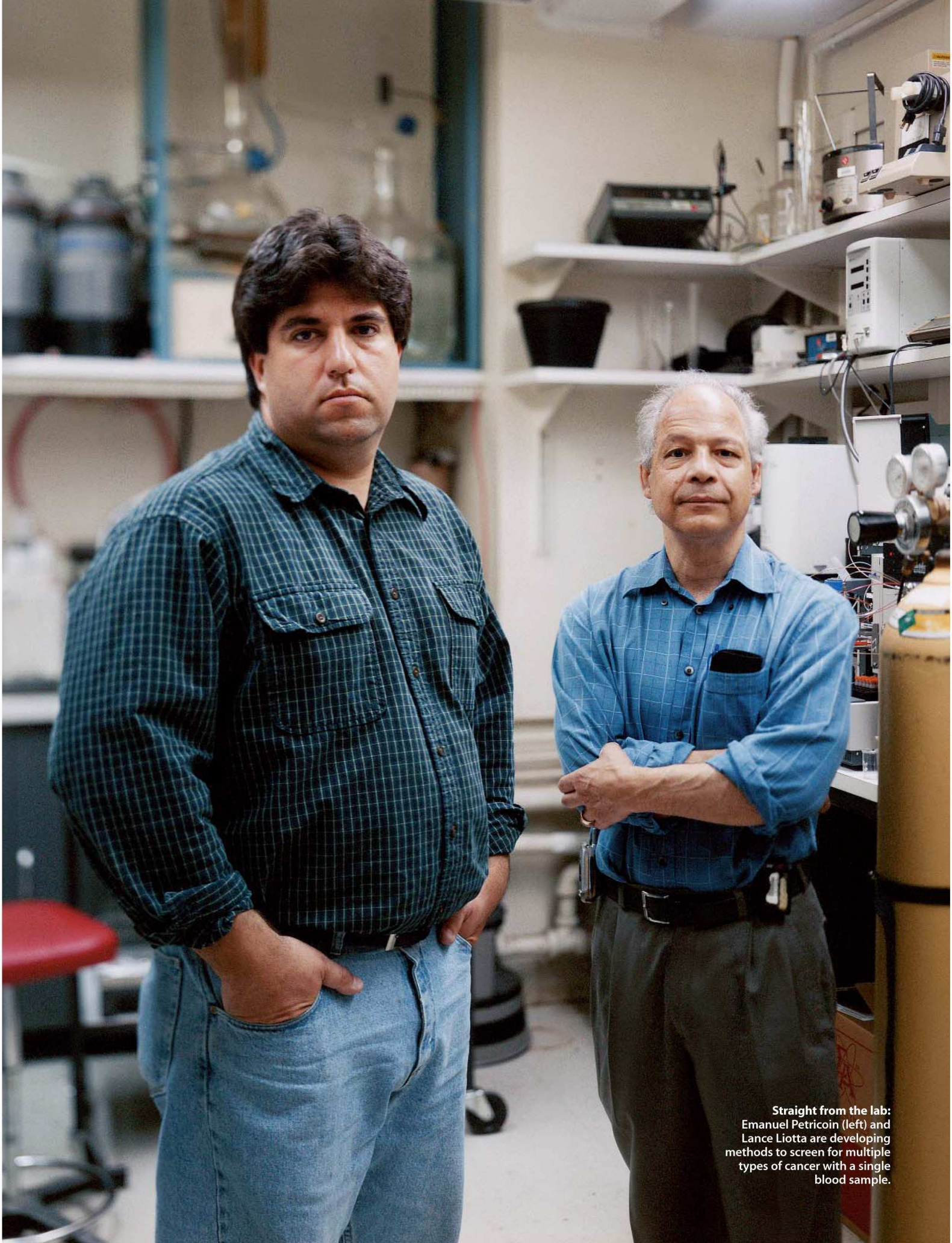
WILLIAM BIGBEE
LOCATION: University of Pittsburgh
CANCER TARGET: Pancreatic, head and neck, breast, lung
STATUS: Preliminary studies

LANCE LIOTTA, National Institutes of Health, and **EMANUEL PETRICOIN**, U.S. Food and Drug Administration
LOCATION: Bethesda, MD
CANCER TARGET: Ovarian, pancreatic, lung, prostate
STATUS: Ovarian test for disease recurrence in human research trial; 2007 completion

PIERRE MASSION
LOCATION: Vanderbilt University, Nashville, TN
CANCER TARGET: Lung
STATUS: Preliminary studies

JOHN SEMMES
LOCATION: Eastern Virginia Medical School, Norfolk, VA
CANCER TARGET: Prostate, head and neck, leukemia, lymphoma
STATUS: Prostate test undergoing multicenter human research trials; 2006 completion

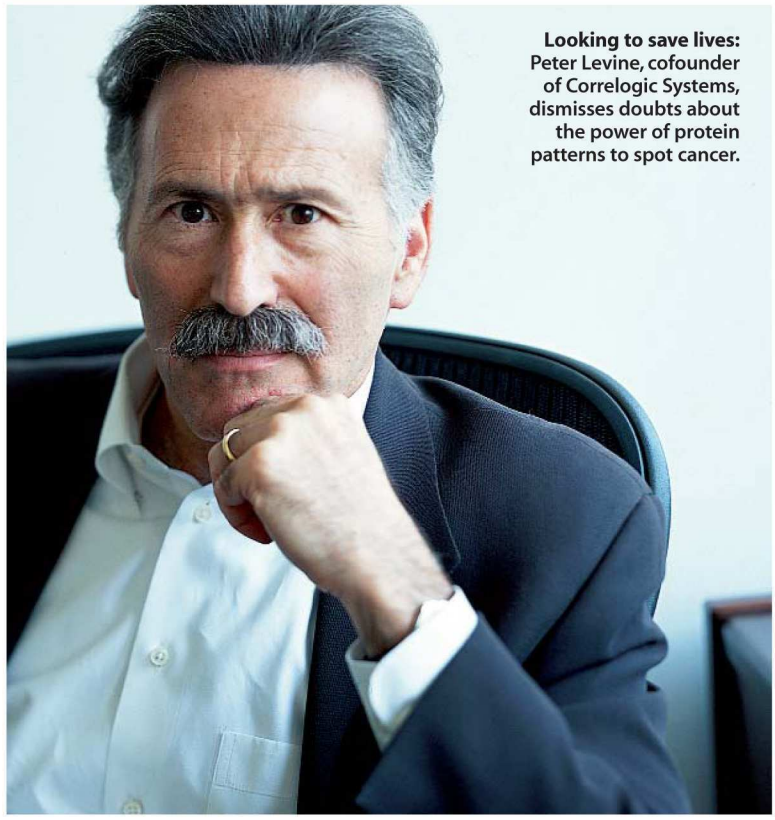
*all tests use a blood sample unless otherwise noted



Straight from the lab: Emanuel Petricoin (left) and Lance Liotta are developing methods to screen for multiple types of cancer with a single blood sample.

The field must also cope with a scientific backlash against the whole idea of protein pattern diagnostics. Eleftherios Diamandis, a cancer expert at the University of Toronto in Ontario, calls the original *Lancet* ovarian-cancer paper "complete junk." Diamandis contends that the patterns don't actually represent proteins produced by cancer cells. "The technology will fail, because the molecules they monitor are not the correct ones," says Diamandis. "I don't think mass spectrometry, the way they perform it, is sensitive enough." Instead, he urges, identify the proteins behind the peaks first, to make sure they're really cancer proteins, and then develop standard tests to detect them. "Then we can put them all together, and we can make a reasonably good clinical diagnosis," Diamandis says.

Petricoin firmly believes that the instruments are following proteins from cancer but concedes that proof can come only from rigorous trials. "The only way to prove it's real or not is by validation, like any biomarker," he says. The effort is worth it, he adds, because generating patterns is relatively simple, while identifying proteins and translating that knowledge into a useful lab test could take years, even before clinical trials. "The debate about whether or not it's critical to identify the particular proteins or other molecules that make up a pattern, that's [arguing] how many angels dance on the head of a pin," agrees Levine. "If what you can do in the near term is develop diagnostics that will save lives, to me that's the beginning of the end of the discussion."



Looking to save lives: Peter Levine, cofounder of Correlogic Systems, dismisses doubts about the power of protein patterns to spot cancer.

TESTING THE FUTURE

Petricoin and Liotta, also undeterred by critics, are moving steadily forward, albeit separately from Correlogic. They're assessing their own ovarian-cancer test in a clinical trial for women in remission, to detect return of the disease. They intend to submit the method for FDA review and to license the related technology nonexclusively to any company interested in offering it.

The two scientists are also preparing similar tests for pancreatic, lung, and prostate cancers. They envision a future in which a small blood sample, periodically drawn in the doctor's office, will reveal a complete image of the current disease status of the entire body. "Our goal is to show that in fact you can come up with a protein pattern that can discriminate disease and for the [National Cancer Institute] to take that all the way to FDA approval," says Petricoin.

But the first diagnostic test based on protein profiling will probably be an ovarian-cancer test from Ciphergen, the company whose machine started it all. Ciphergen is not using a pattern per se but is instead sticking with its initial, more conservative approach: using protein patterns to find markers that are then individually identified and validated for their ability to distinguish cancer from noncancer.

OVARIAN CANCER

90

Percentage of patients who can be cured if diagnosed early

The company is fashioning tests that use mass spectrometry to detect these specific markers, as opposed to the overall protein pattern. Ciphergen is also working on pancreatic- and prostate cancer tests, but its ovarian-cancer test—based on three protein markers—is the most advanced. "Our goal is to commercialize the test by the end of this year or early next year," says Gail Page, president of Ciphergen's diagnostics division.

Whether it will open the floodgates for similar tests depends on how well it performs. But Ciphergen is committed to using protein profiling as the basis for new and better cancer diagnostics. "We believe it will be the wave of the future," says Eric Fung, Ciphergen's director of clinical affairs and one of the originators of the ovarian-cancer test. "There is a transition from single markers to multiple markers, and…someday it will evolve to patterns," he says. "It's my personal view that we may end up there, but we're not there yet."

Many enterprising scientists and companies, however, are betting that patterns will be ready for use within just a few years. And they expect patterns to diagnose cancer earlier, more accurately, and more reliably than a limited set of known markers like Ciphergen's, however well chosen. Wright, for instance, though now retired and playing an advisory role, still continues his quest for an accurate cancer test based on pattern recognition. Four decades of failure have taught him to be cautious, but he can't hide his excitement. "It will take several years for us to know whether this can be definitely proven to be useful," he says. Still, he adds, "It's very exciting, highly promising."

Tests based on protein patterns, if they work, could help to save millions of lives. But as Wright and other cancer researchers well know, they aren't the last word in cancer diagnosis. "There's no magic elixir," says Petricoin. "Nothing's going to replace a smart doctor working with a patient."

Ken Garber is a freelance science writer based in Ann Arbor, MI.

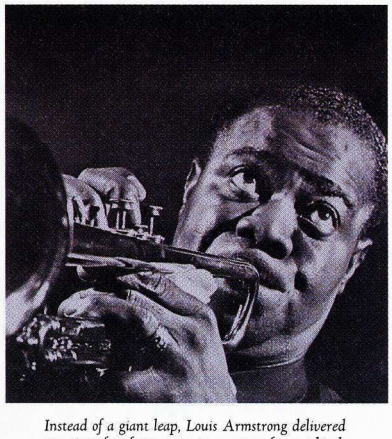
THERE'S NOT ENOUGH ART IN OUR SCHOOLS.

NO WONDER PEOPLE THINK

LOUIS ARMSTRONG

WAS THE FIRST MAN TO WALK ON THE MOON.

It's a long way from the Apollo Theatre to the Apollo program. And while his playing may have been "as lofty as a moon flight," as *Time* magazine once suggested, that would be as close as Louis Daniel Armstrong would ever get to taking "one small step for man."



Instead of a giant leap, Louis Armstrong delivered one giant free-form crazy jazz groove for mankind.

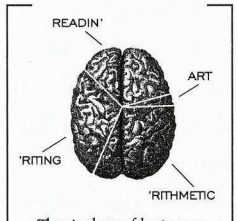
But as the jazz musician of the 20th century, giant leaps were simply a matter of course for Satchmo. For no one has ever embodied the art form the way he did. It was he who helped make virtuoso solos a part of the vocabulary. It was he who was honored with the title "American goodwill ambassador" by the State Department. It was he who was the last jazz musician to hit #1 on the Billboard pop chart.

Armstrong left his footprints on the jazz world, wearing lace-up oxfords.

Not bad for a kid whose first experience with the trumpet was as a guest in a correctional home for wayward boys. If only today's schools were as enlightened and informed as that reformatory was.

Alas, the arts are dismissed as extravagant in today's schools. This, despite all the studies that show parents believe music and dance and art and drama make their children much better students and better people.

If you feel like your kids aren't getting their fair share, make some noise. To find out how, or for more information about the benefits of arts education, please visit us on the web at AmericansForTheArts.org. Just like the great Louis Armstrong, all you need is a little brass.



There's plenty of brain to go around. Give more to art.

ART. ASK FOR MORE.

Ad Council

For more information about the importance of arts education, contact www.AmericansForTheArts.org.

Photo used with permission, Louis Armstrong Educational Foundation.

AMERICANS for the ARTS

DORIS DUKE CHARITABLE FOUNDATION

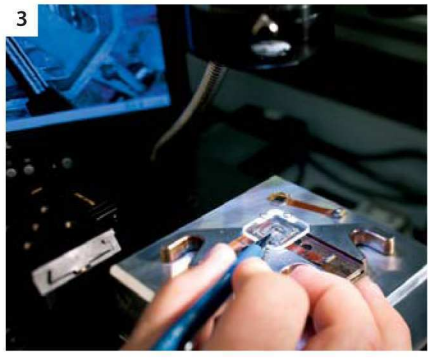
WEARABLE ROBOTS

EXOSKELETONS AREN'T JUST FOR ANTS ANYMORE. **STEPHEN JACOBSEN IS DEVELOPING A POWERED SUIT** THAT COULD GIVE SOLDIERS AND RESCUE WORKERS SUPER STRENGTH—AND EVENTUALLY ALLOW DISABLED PEOPLE TO WALK.

STORIES ABOUT SUPERHUMAN strength permeate popular culture from Atlas to Zeus, Superman to Schwarzenegger. But now, says University of Utah robotics expert Stephen Jacobsen, it's time to deliver in the real world. With funding from the U.S. Department of Defense, Jacobsen's Salt Lake City-based company, Sarcos, has built a robotic suit that does just that. A person wearing this powered "exoskeleton" on his or her legs can carry massive loads without getting tired. Exoskeletons could enable soldiers to haul heavier equipment over greater distances, allow rescue workers to carry survivors more safely, and eventually help disabled people get around. It's a daring vision—and Sarcos is hardly the first group to pursue it—but Jacobsen seems a good bet to do it right. Over the course of his career, the prolific inventor has developed standout devices that include the world's leading powered prosthetic arm and the dancing fountains of the Bellagio hotel in Las Vegas—all using the most advanced robotics technologies available. And while it may take years to make exoskeletons practical for widespread use, Jacobsen says, "before you do it right, you have to do it at all." This spring, he gave *TR* associate editor Gregory T. Huang an exclusive tour of Sarcos and showed how the company goes about building a wearable robot.

PHOTOGRAPHS BY ERIK ÖSTLING

Walking tall: Stephen Jacobsen at Sarcos straps on a robotic exoskeleton that enhances lower-body strength.

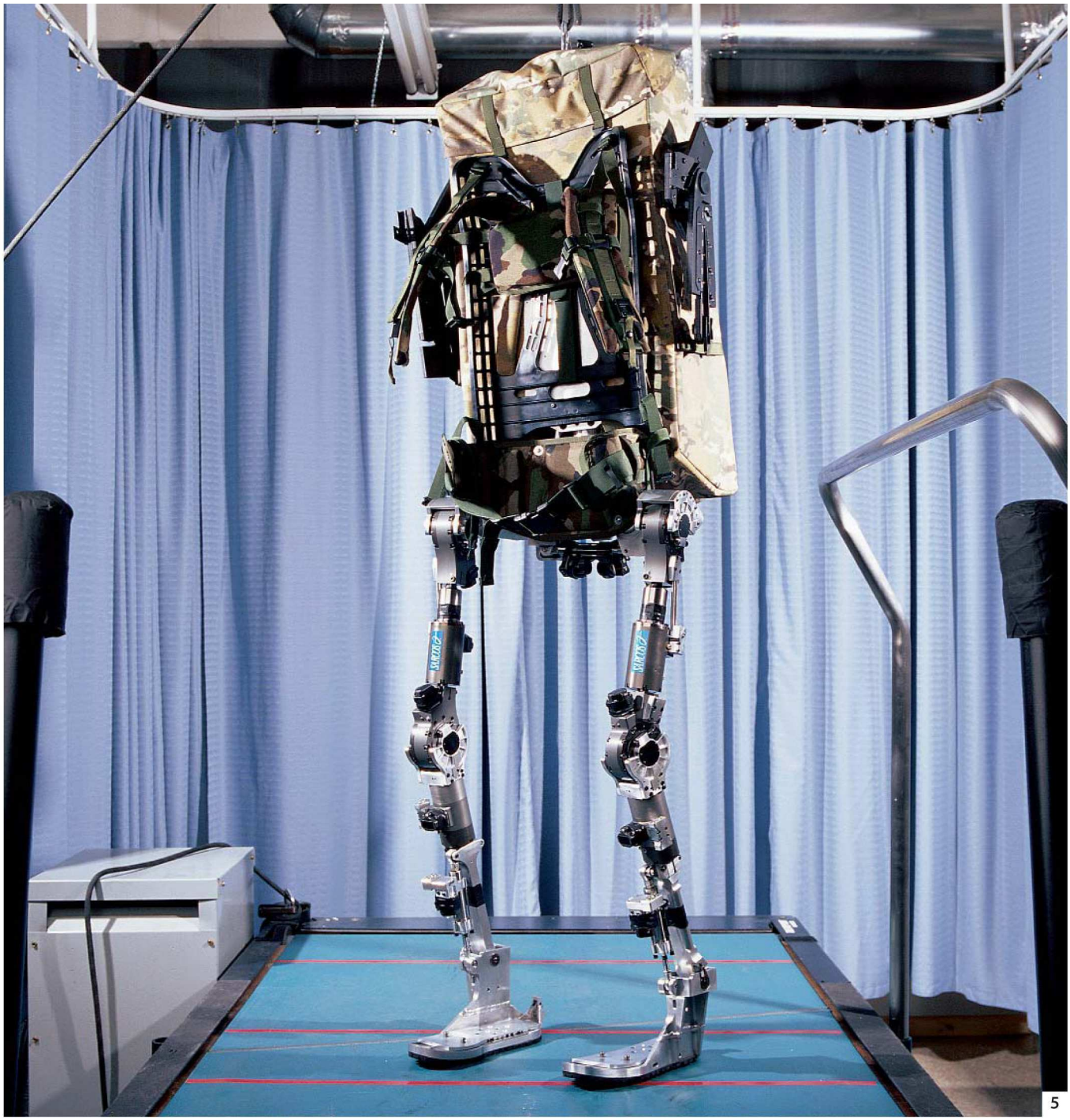


1. SENSOR SUIT. Jacobsen walks into a bustling hangar-like hall and points out a yellow contraption the size of a person. The first step in designing the exoskeleton, he explains, was building this plastic mock-up of the device that designers could use to gather data about how the human body moves. Volunteers donned the suit, and its 30 position sensors measured the range of motion and timing of each joint as they walked, ran, jumped, twisted, and squatted. The data were used to help create a computer model of the exoskeleton.

2. MINI MODEL. But to see how various designs will work, it helps to build physical models too. In an equipment room down the hall, designer Jon Price positions a miniature wooden model of the exoskeleton next to a quarter-scale clay sculpture of a person. This setup, he says, allows researchers to see whether the machinery around a joint will bump into itself, for instance. "You build and you analyze, hand in hand," says Jacobsen. And it's a lot easier to make changes to the design at this scale.

3-4. STRONG AND SENSITIVE. Once the basic exoskeleton design is in place, the researchers turn their attention to the details of building it. At a fabrication test station, for example, an engineer tunes a force sensor that goes in the exoskeleton's pelvis (3). The robotic suit must sense what the user is doing and help him or her to do it without restricting movement. A bit like power steering, the control system is what Jacobsen calls "get-out-of-the-way control." To make it work, sophisticated sensors like this one are needed at every leg joint and in the platforms beneath the user's feet. At an actuator test station, Jacobsen shows how researchers power up one such joint with hydraulics, the stuff that drives construction equipment and car brakes (4). Using a bank of hydraulic valves, researchers test how the joint behaves when driven by different fluid pressures and speeds. One of Sarcos's big advances, says Jacobsen, is building machines that can be strong, fast, *and* dexterous.

5. I, ROBOT. In a large room next to the hangar, Jacobsen unveils the end result of all this tinkering: a prototype lower-body exoskeleton, standing on a treadmill behind a blue curtain. Each leg has powered joints at the hip, knee, and ankle and about 20 sensors, all coordinated by an onboard PC in a backpack attached to



5

the frame. Strap it on, go for a walk on the treadmill or up and down stairs while carrying a 90-kilogram load on your back, and it feels as if you're carrying nothing, says Jacobsen. You can even balance on one foot with a person on your back and barely feel any more fatigued than if you were standing by yourself, he adds. The exoskeleton adds strength because it stays in parallel with the user's legs and pushes on the ground. But this is just a test unit, says Jacobsen. "When you start building systems of elements, all of which are complex, and you put them together," he says, "you have to test if they work together in a combined way."

6. POWER PACK. For now, the exoskeleton's power comes from hydraulic pumps in the wall or from a backpack-size internal-combustion engine with a fuel tank that generates hydraulic power. Jacobsen points out this portable engine in the hangar and explains that Sarcos is working on a smaller, more efficient power source for its next-generation exoskeleton, which will be lighter, stronger, and more user friendly. Ease of use is important, says Jacobsen, because in the end this project is about "saving lives and going further distances." Indeed, with powered exoskeletons, Sarcos hopes to take the field of wearable robots further than it has ever gone before. TR

6

Tracking Privacy

BY ERIKA JONIETZ | Photograph by Michael Wilson

TECHNOLOGY REVIEW: How would RFID work to track products?
SANDRA HUGHES: It's a technology that involves a silicon chip and an antenna, which together we call a tag. The tags emit radio signals to devices that we call readers. One of the things that is important to know about is EPC. Some people use RFID and EPC interchangeably, but they are different. EPC stands for electronic product code; it's really like an electronic bar code.

TR: So manufacturers and distributors would use EPCs encoded in RFID tags to mark and track products? Why's that any better than using regular bar codes?
HUGHES: Bar codes require a line of sight, so somebody with a bar code reader has to get right up on the bar code and scan it. When you're thinking about the supply chain, somebody in the warehouse is having to look at every single case. With RFID, a reader should be able to pick up just by one swipe all of the cases on the pallet, even the ones stacked up in the middle that can't be seen. So it's much, much faster and more efficient and accurate.

TR: Why is that speed important?
HUGHES: We want our product to be on the shelf for consumers when they want it. A recent study of retailers showed that the top 2,000 items in stores had a 12 percent out-of-stock rate on Saturday afternoons, the busiest shopping day. I think the industry average for inventory levels is 65 days, which means products sitting around, taking up space for that time, and that costs about $3 billion annually. Often a retail clerk can't quickly find products in the crowded back room of a store to make sure that the shelves are filled for the consumer, or doesn't know that a shelf is sitting empty because she hasn't walked by lately. With RFID, the shelf can signal to the back room that it is empty, and the clerk can quickly find the product.

TR: Are these tags being used already?
HUGHES: A number of tests have been and are continuing to be done to evaluate and improve the technology. Primarily it's been at the case level and pallet level, but sometimes it will be to the shelf, because in the end, the goal is to make sure that the right product is on the shelf for consumers to buy when they want it. There's a lot of learning that still has to go on with the reliability of being able to read these tags, because if you're going to use them to track products through their life cycles, you need the information to be accurate.

TR: Does that mean tracking a product even after a buyer has brought it home?
HUGHES: No. Our focus is making sure the product's there on the shelf. So to me, that's the life cycle.

TR: How long will it take until we see these tags regularly?
HUGHES: That's going to be spread out over several years. What's moving it along are mandates by retailers like Wal-Mart, Target, Metro in Germany, and Albertsons. The Wal-Mart mandate is that by January, their top 100 suppliers would be tagging pallets and cases of all of their products. In the next year or two, consumers are going to be seeing tags on cartons for big items, like computer equipment or furniture, for example. But for individual items like shampoo bottles, I think we're talking eight to 10 years out.

TR: Some of the retailers, such as Wal-Mart and Metro, have seen consumer backlash over privacy concerns. Why is that?
HUGHES: The most widely publicized privacy concern is that the EPC would be linked to personally identifiable information. The tags themselves don't have any personally identifiable information, but the fear is that the number will be linked somehow to personal information. The other fear is that tracking or surveillance will go on outside the store—that an individual could be tracked to their home or so on because they have a tag on one of the products that they've purchased.

TR: Are those realistic worries?
HUGHES: They're concerns that consumers have, so they are real to them and something that we feel needs to be addressed. But there are solutions for everything. If you think about it, the linkage in a retail store to personally identifiable information would be done just as it is today with bar codes. Whether consumers know it or not, if they have a loyalty card, the personal information that they have provided to get that card and all of the discounts and coupons that go with it must be linked to the bar codes of items that they purchase. So when you think about the electronic product code—this is the same thing.

TR: So you couldn't track someone using a tag in his shirt or on a tube of toothpaste?
HUGHES: The scenario I've heard is, "Somebody would be able to know every place I've been all throughout the day." Let's say that you went to a restaurant, and you went to a grocery store, and you went here or there. Wherever that tag is being read, that place would have to also have your personal information. And those locations would all have to be sharing information for someone to put it together and say, "This person went to this restaurant and this grocery store." I can't imagine businesses sharing that information about customers when you think that a lot of them are competing with each other.

TR: What about being able to follow someone directly using a tag, the way intelligence agencies have tracked terrorists using their cell phones?
HUGHES: Assuming you knew someone's identity and wanted to follow him using the tag like a homing device, you would have to be quite close to the person to "read" that tube of toothpaste. These are passive tags, which means they have no battery and don't emit any signal unless a reader "wakes them up." If you were going to stalk somebody, you don't want to be seen. That's going to be pretty difficult to do with passive tags.

TR: What about stores? Could the tags allow retailers to go even further in tracking customers and their buying habits?
HUGHES: Well, the EPCglobal community has developed a set of usage guidelines. One of the things it says is that if a retailer is going to use the EPC information combined with personal information in any way differently than they do with bar codes today, then they need to make that information and choices available to the consumer. But to my knowledge, nobody has any plans to do that today.

TR: What if I'm freaked out anyway that you know exactly which tube of toothpaste I bought, and it has this working tag on it?
HUGHES: These guidelines cover the basic tenets of privacy, which are that you let the consumer know that there is a tag on the product. And then they would be given a choice on disabling or deactivating those tags. But because the technology is in its infancy, there are not a lot of solutions yet. Basically, the tag can be removed or the packaging thrown away.

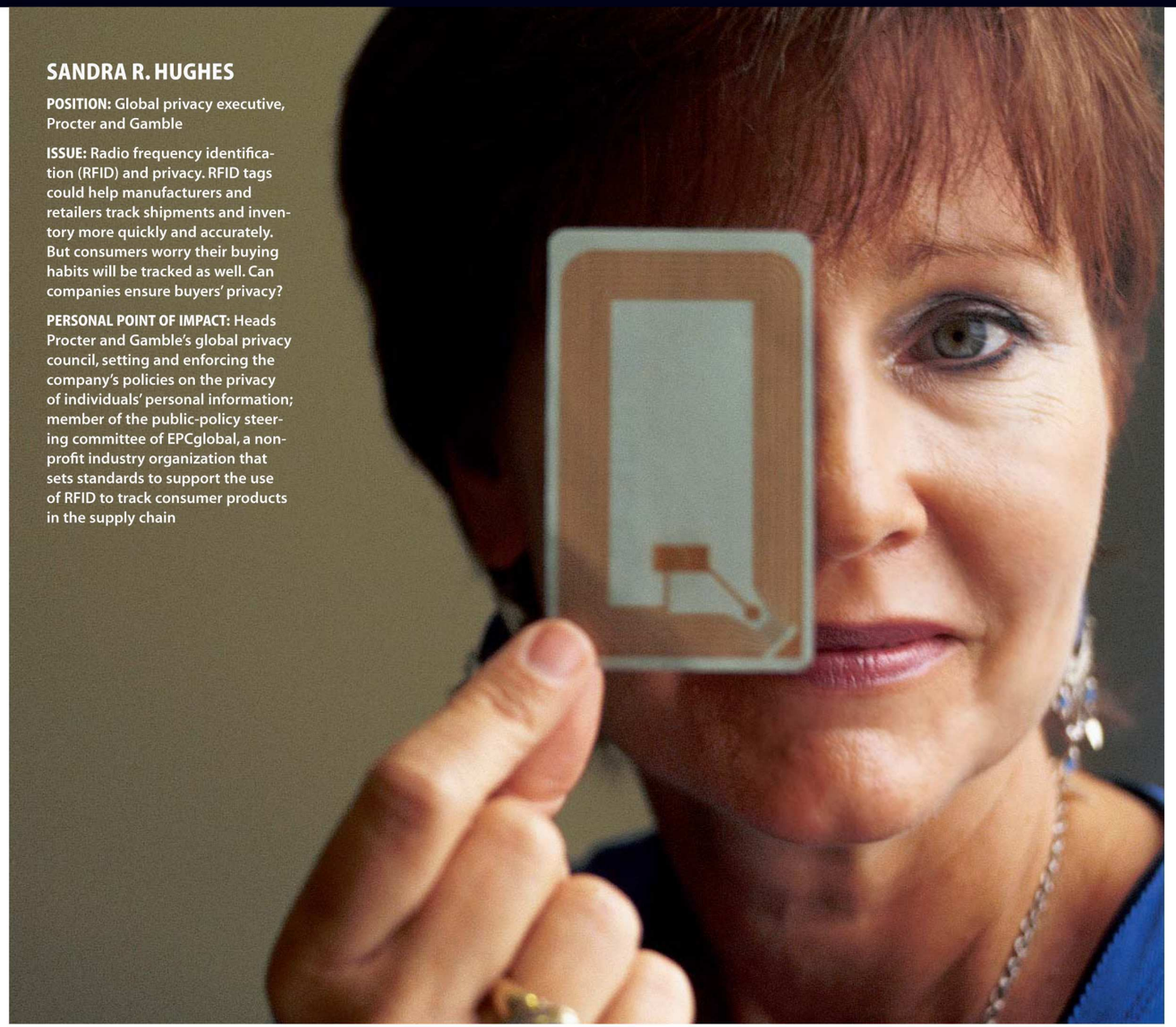
TR: That's it? I can peel it off?
HUGHES: Yes, or don't buy the product. There will be other solutions—deactivation, either full or partial, I don't know what else—all of which are still being developed and tested. We're going to see a lot of developments, and it is really quite exciting to think about the way things will be five years from now. Already ideas are popping up—like blocker tags, or a metal shopping bag, because RFID can't go through metal. There's a lot of creativity that is still to come. TR

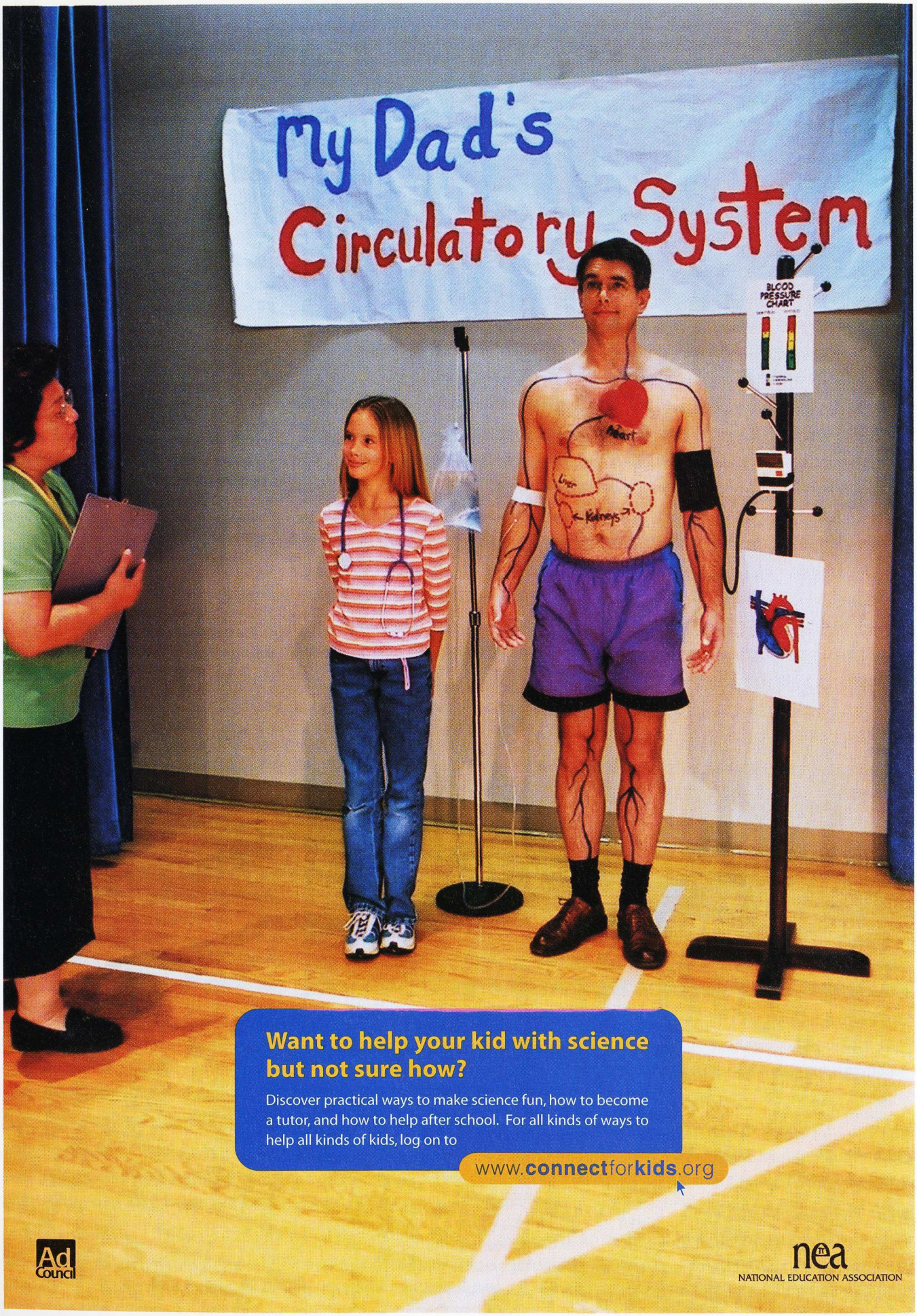
SANDRA R. HUGHES

POSITION: Global privacy executive, Procter and Gamble

ISSUE: Radio frequency identification (RFID) and privacy. RFID tags could help manufacturers and retailers track shipments and inventory more quickly and accurately. But consumers worry their buying habits will be tracked as well. Can companies ensure buyers' privacy?

PERSONAL POINT OF IMPACT: Heads Procter and Gamble's global privacy council, setting and enforcing the company's policies on the privacy of individuals' personal information; member of the public-policy steering committee of EPCglobal, a nonprofit industry organization that sets standards to support the use of RFID to track consumer products in the supply chain

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Worm Guards

BY CORIE LOK

It's becoming almost commonplace these days. Computer users and IT managers fend off a worm attack, then spend countless hours and dollars cleaning up the damage and downloading patches for future protection. Amid the growing number of attacks, Determina, an MIT spinoff based in Redwood City, CA, has stepped into the fray with software it says will better protect computers against worms while requiring minimum maintenance.

DETERMINA

HEADQUARTERS: Redwood City, CA

UNIVERSITY: MIT

INVESTMENT RAISED: $19 million

LEAD INVESTORS: Bessemer Venture Partners, Mayfield, U.S. Venture Partners

KEY FOUNDERS: Saman Amarasinghe, Derek Bruening, and Vladimir Kiriansky

Determina's product, SecureCore, runs on servers (a desktop version is in planning) to guard against worms, which have become the most common method of attacking computers. Worms are malicious programs that rapidly and automatically spread via networks, including the Internet. They enter a computer posing as normal data, trick it into running their code, take control of the computer's programs, and move on to the next computer. Protection against worms—particularly new ones—is tricky, and existing antiworm software typically requires ongoing maintenance. Determina's software, on the other hand, demands no work from the user beyond its initial installation, so it can be deployed on computers across an entire enterprise instead of on just a few key servers, says Nand Mulchandani, Determina's CEO.

The company released its software at the end of February and by April had raised $16 million in second-round venture financing. Since its founding last May, Determina has changed its name from Araksha and signed on two customers: an unnamed federal agency and Thermo Electron, a Waltham, MA-based manufacturer of lab equipment. Determina is pursuing other government agencies as customers, as well as telecom and financial companies, where security is a high priority.

First-generation antiworm technologies rely chiefly on recognizing the distinctive characteristics of particular known programs, but that approach works only after attacks have been unleashed and analyzed. It's useless at protecting against new and unknown intrusions, especially ones that spread within a few hours. More recent software learns to distinguish between normal and abnormal application behavior, but operating systems and application programs are now so complex, running an enormous range of code in so many different ways, that such distinctions are often difficult to make accurately, says Saman Amarasinghe, Determina's cofounder, who is on leave from MIT's Department of Electrical Engineering and Computer Science to serve as the company's chief technology officer.

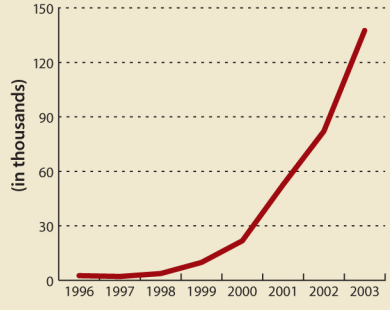
In contrast, Determina's software works by closely monitoring a fundamental set of instructions common to most applications. These instructions are the worm writer's favorite target. By breaking the rules that govern them, a worm can run its own code, take control of the application, and propagate itself. SecureCore, which sells for between $500 and $1,500 for each server, makes sure these rules aren't broken. Because the rules are universal to all applications running on a particular operating system, such as Windows, and violating them is almost always a malicious activity, this is a more accurate method of spotting intrusions, and one that doesn't require any updates or a "learning" period, says Amarasinghe.

"[Its] approach is really new and innovative," says Eric Ogren, senior analyst with the Yankee Group in Boston. "It has great potential to make IT's life easier in protecting servers and desktops from malicious attack, without a lot of overhead."

The company still needs to validate its technology with more customers. But with 83 percent of large companies experiencing worms or viruses last year, according to a Yankee Group survey, Determina is primed to take advantage of the need for an effective defense against these increasingly common computer attacks. TR

COMPUTER INVASIONS

Number of incidents, including worms, reported to the CERT Coordination Center, a reporting center for Internet security problems at Carnegie Mellon University



SOURCE: CERT COORDINATION CENTER

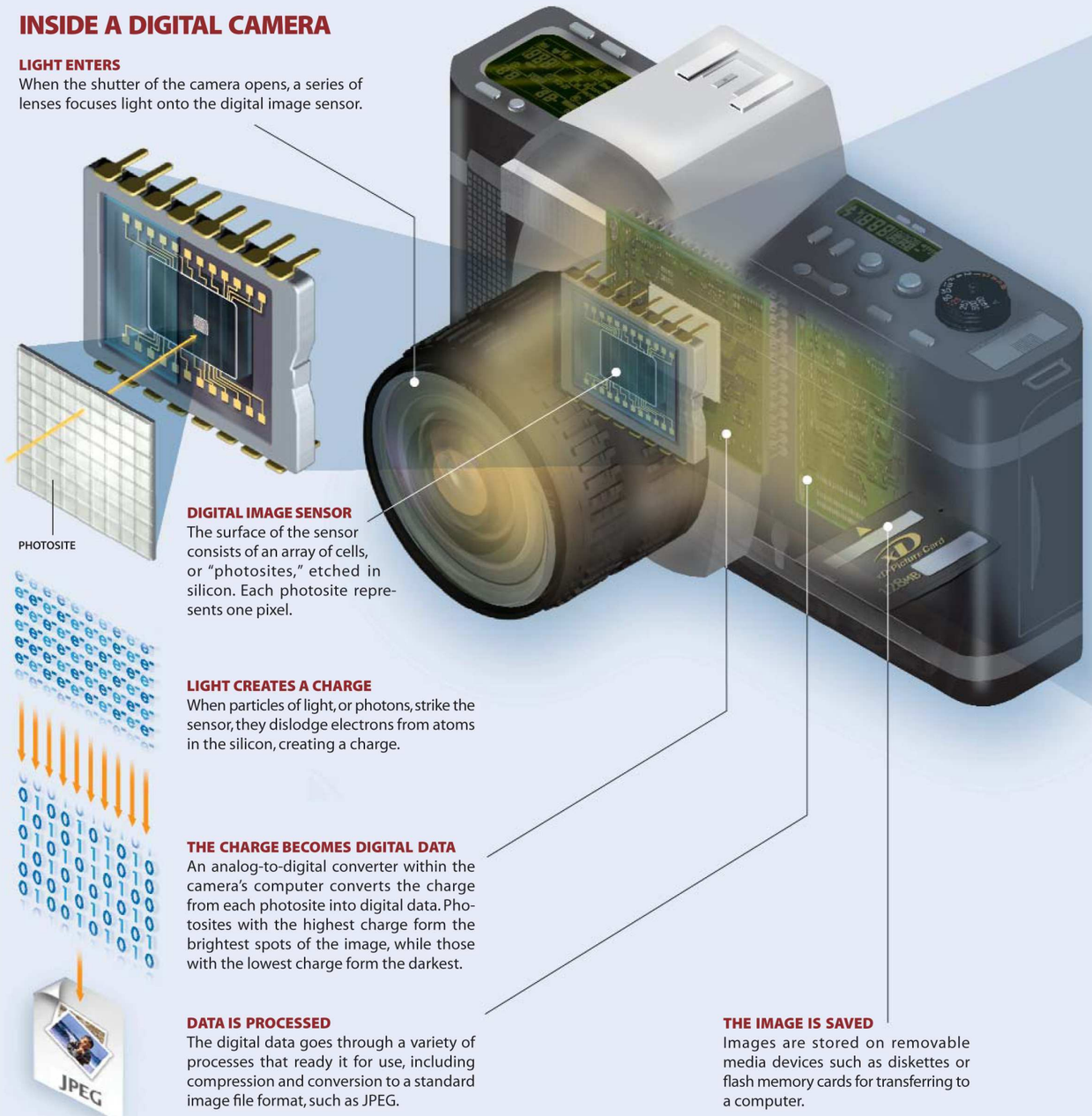
SOME OTHER COMPUTER ANTI-INTRUSION SOFTWARE

COMPANY	TECHNOLOGY
Cisco Systems (San Jose, CA)	Security Agent software protects servers and desktops
Network Associates (Santa Clara, CA)	McAfee Entercept software recognizes signatures of attacks and sequences of instructions that define normal behavior
Sana Security (San Mateo, CA)	Software "learns" normal application behavior and detects and stops abnormal behavior on servers
Symantec (Cupertino, CA)	Host IDS software detects and prevents intrusions on servers

Digital Image Sensor

In North America, digital cameras may nearly replace film cameras by 2008, according to InfoTrends/CAP Ventures, a digital-imaging market research firm in Weymouth, MA. The trend is being fueled partly by improvements in the digital sensors that capture images in lieu of film. The latest sensor is the X3 from Santa Clara, CA-based Foveon. It has three layers of silicon, as opposed to one in conventional sensors, which produce sharper, truer-colored photos. Until now the X3 was used only in professional-grade cameras, but Foveon partnered with Polaroid and this summer released an X3-based camera that retails for about $400. Here's how it works, and how it compares to conventional digital technology and to film. **TEXT AND ART BY 5W INFOGRAPHIC**

INSIDE A DIGITAL CAMERA



LIGHT ENTERS
When the shutter of the camera opens, a series of lenses focuses light onto the digital image sensor.

DIGITAL IMAGE SENSOR
The surface of the sensor consists of an array of cells, or "photosites," etched in silicon. Each photosite represents one pixel.

LIGHT CREATES A CHARGE
When particles of light, or photons, strike the sensor, they dislodge electrons from atoms in the silicon, creating a charge.

THE CHARGE BECOMES DIGITAL DATA
An analog-to-digital converter within the camera's computer converts the charge from each photosite into digital data. Photosites with the highest charge form the brightest spots of the image, while those with the lowest charge form the darkest.

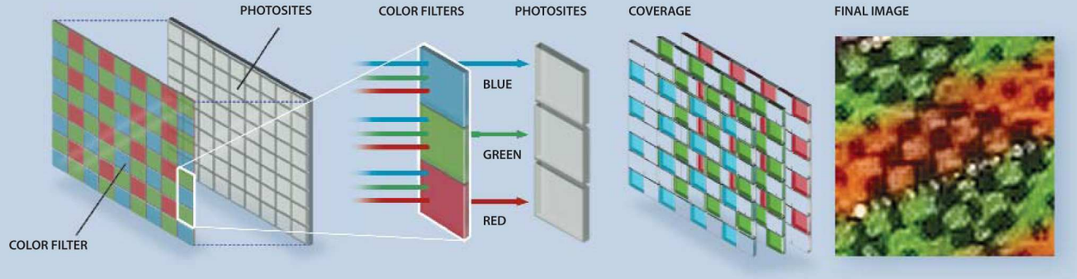
DATA IS PROCESSED
The digital data goes through a variety of processes that ready it for use, including compression and conversion to a standard image file format, such as JPEG.

THE IMAGE IS SAVED
Images are stored on removable media devices such as diskettes or flash memory cards for transferring to a computer.

SENSING COLOR: THE DIFFERENT WAYS

Conventional digital sensors use color filters in red, green, and blue, because while photosites can record the intensity of light, they cannot detect color. But the Foveon X3 does not use filters; rather, it employs three layers of photosites that absorb red, green, and blue wavelengths of light, respectively. The technology is similar to film, which has three layers of chemical emulsion sensitive to color.

Conventional Digital Image Sensor

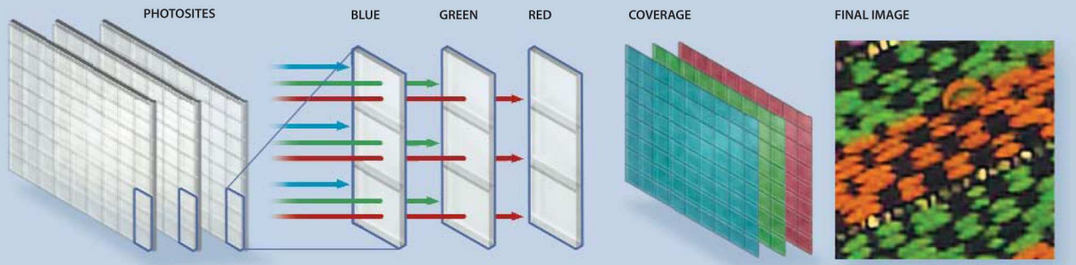


Color filters are applied to a single layer of photosites in a mosaic pattern that uses two green filters for every red or blue filter because the human eye is more receptive to green.

Each filter lets only one color of light pass through to the photosite underneath. The photosite records the intensity of that color at that spot.

Because the sensor captures only 25 percent of the red and blue light and 50 percent of the green, an image processor must fill in the undetected colors using mathematical interpolation. The resulting image can be blurred and discolored.

Foveon's X3 Sensor



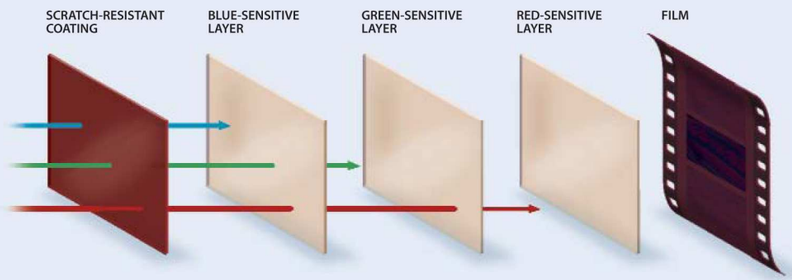
Three layers of light-sensitive photosites embedded in silicon collect light.

Each layer captures a different wavelength of light.

Every pixel in the final image contains color data gathered by one photosite in each of the three layers, resulting in sharper images with more color details.

Film

Color film has three layers of chemical emulsion composed of millions of light-sensitive silver-salt crystals. Each layer is sensitive to a different color of light, enabling the film to record red, green, and blue light at every point in the image.



The Tablet PC Nonrevolution

I ORDINARILY TYPE MY COLUMNS. BUT SINCE THIS column is about tablet computing, I decided to compose it in longhand on the Compaq tc1100 tablet computer that Hewlett-Packard lent me earlier this year. ▪ For people who never learned typing, or for those who find it a painful chore, writing on a computer's screen and having your words turned into beautiful text must be a liberating experience. I'll never know: I learned to type when I was in ninth grade and can easily crank out 120 words per minute. Still, Microsoft's Tablet PC edition of Windows XP has a handwriting recognizer that's nearly flawless. This computer was able to recognize my weird mixture of printing and cursive the very first time I picked up the stylus: neither I nor the computer required any training. The tablet PC could even recognize my seven-year-old daughter's handwriting—misspellings and all! In fact, it corrected each word as she went on to the next.

Driving this high-quality handwriting recognition is an incredibly rich dictionary (built from millions of handwriting samples), spelling and grammar smarts, and software that takes into account not just the electronic "ink" left on the page but the movement of the pen as you write. None of it would be possible without today's fast processors and huge memory chips. Computer hardware just wasn't up to the task a decade ago, when Garry Trudeau lambasted the Apple Newton in *Doonesbury*. Today the tables have turned.

But while entering text is a joy with this computer, going back and editing it is painful. It's easy to correct the occasional mistake that the recognizer makes by selecting the word and then choosing an alternative interpretation from a pull-down menu. Serious moving around of words or ideas, though, is better left to the keyboard. That's because precision counts when editing, and it's all too easy, when wielding a stylus, to get a punctuation mark wrong or flummox a word into something that looks the same on the tablet PC's small screen but has a completely different meaning.

Tablet PCs spend a large part of their lives serving as traditional laptops, with the stylus snug in its holster while the keyboard gets a vigorous workout.

That's why just about every tablet PC on the market today has a keyboard hidden underneath the writing surface. Just lift up the screen, spin it around some hidden hinge, and—voilà!—you have a traditional (albeit expensive) laptop computer. And from my people-watching around MIT, it seems that tablet PCs spend a large part of their lives serving as traditional laptops, with the stylus snug in its holster while the keyboard gets a vigorous workout.

Tablet computing isn't exactly a fraud, but it's not the revolution that PC makers would like it to be. I find it a lot easier to read text on the flat tablet than on a clamshell laptop. And for applications like taking inventory or filling out surveys, the tablet format is clearly superior. My daughter sure likes curling up with the tablet on our couch while she surfs those kids' websites. And PC makers love the way that turning a laptop into a tablet lets them add $500 or more to its price.

But Microsoft is selling the tablet short by trying to make it operate within the traditional Windows framework. The menu bars, pop-up controls, and scroll bars of Windows have evolved over the past 20 years for a computer that's driven with a keyboard and mouse—not a pen. It's downright awkward to try to fill a text field by tapping it and then writing in the recognition area.

One of the reasons that the original Palm Pilot was so successful is that its developers weren't afraid to experiment with new and frequently simpler interaction paradigms. Palm developed on-screen widgets that were easy to use on a small display amidst a lot of visual distractions. It came up with a fast way to switch between applications and an integrated database that freed users from thinking about files and folders. Yes, you can configure the Tablet PC version of Windows XP to let you enter text anywhere, but Microsoft Word still thinks that you are using a keyboard and a mouse. Word doesn't know about gestures like proofreader's marks—things that are easy to write with a pen but nearly impossible to input with a mouse.

One good thing about tablets is that they're pushing PC laptops in the right direction. The tc1100 unit that I tested weighs just 1.8 kilograms (four pounds), yet it is loaded with input/output options including two USB ports, Ethernet, Wi-Fi wireless networking, and a dial on the side for fast scrolling. As these machines become more prevalent, I'm hoping that the software catches up.

Because it sure is comfortable to lie back on my couch while surfing those websites: the tablet is lighter, easier to hold, and easier to read, and the clamshell doesn't get in my way.

Simson Garfinkel is an incurable gadgeteer, an entrepreneur, and the author of 12 books on information technology and its impact.

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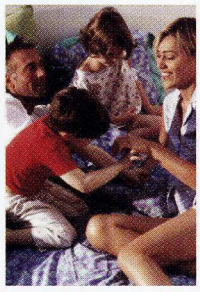

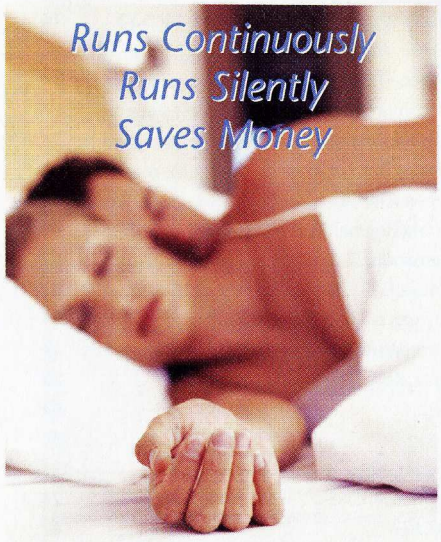

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Radioplane's RP-5A drones, dubbed TDD-1 (for Target Drone Denny), were used by the thousands during World War II.

Radio Flyer

Reginald Denny's passion for model-aircraft building helped pave the way for robot planes. BY DAN CHO

In the recent fighting in Afghanistan and Iraq, the U.S. military touted a wealth of new battlefield hardware. Among the more prominent innovations were remotely piloted planes, such as the Predator and Global Hawk, that were prized for surveillance work; some could even fire missiles at enemy targets.

Because of the vehicles' ever increasing capabilities and low cost—both in money and in pilots' lives—their emergence is taken by many as a glimpse into the future of warfare. But unmanned aerial vehicles, like piloted airplanes, have a history that stretches back more than a century and includes many independent inventors and hobbyists. One such pioneer was Reginald Denny. Though he was instrumental in bringing unmanned craft to the military, Denny was better known for his achievements on the silver screen: the British-born actor's name appears in old Hollywood film titles ranging from *Anna Karenina* to *Abbott and Costello Meet Dr. Jekyll and Mr. Hyde*.

Denny had served in the Royal Air Force during World War I, but his interest in radio-controlled planes came about by accident—literally. One day in the early 1930s, Denny was between movie shoots when he encountered a neighborhood boy fiddling with a gas-powered model plane. When the actor tried to help the boy fly the plane, his adjustments caused it to spin out of control. The plane was destroyed, but Denny's fascination with models was born. Denny's hobby soon grew into a business, Reginald Denny Industries, which sold kits for building model planes.

Around that time, the U.S. Army was searching for better methods for training its antiaircraft gunners. The gunners of the day took target practice on unpowered dummy targets towed by piloted airplanes. These were a poor surrogate for powered aircraft, and towing them was undoubtedly a nerve-wracking job.

Denny began working on a radio plane large enough and fast enough to provide a practical target. He and his associates Walter Righter and Paul Whittier demonstrated their first prototype, the RP-1, for the army in 1935. The primitive model was out of their control for most of the flight. Even so, the military could see its potential, and after two more prototypes, the U.S. Army awarded Denny a contract. California-based Radioplane formed in 1940 to manufacture the robot planes; during World War II, the company produced nearly 15,000 of them. Radioplane was purchased by aerospace firm Northrop in 1952, after having made its mark on aviation history.

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